SCIENCE 10

Module 2

Energy Flow in Technological Systems

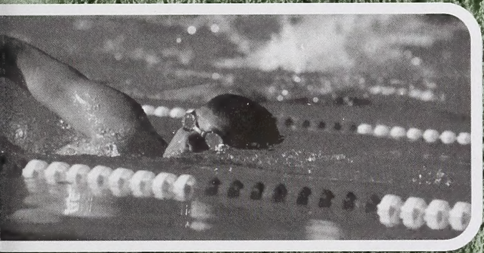
Learning Technologies Branch

Alberta EDUCATION

SCIENCE 10

Module 2

Energy Flow in Technological Systems



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Science 10
Module 2: Energy Flow in Technological Systems
Student Module Booklet
Learning Technologies Branch
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This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

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- Alberta Education, **http://www.education.gov.ab.ca**
- Learning Technologies Branch, **http://www.education.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.education.gov.ab.ca**

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Welcome to

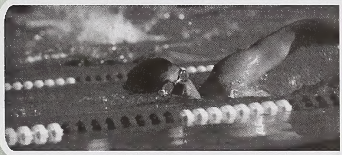
SCIENCE 10

Module 2

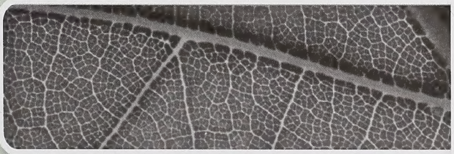
Module 1 contains general information about the course components, additional resources, icons, assessment, and strategies for completing your work. If you do not have access to Module 1, contact your teacher to obtain this important information.

It is recommended that you work through the modules in order (from 1 to 4) because concepts and skills introduced in one module will be reinforced, extended, and applied in later modules.

Module 1
Energy and Matter in Chemical Change



Module 2
Energy Flow in Technological Systems



Module 3
Cycling Matter in Living Systems

Module 4
Energy Flow in Global Systems

Table of Contents

6 **Module Overview**

7 Assessment

8 **Section 1:** Motion and Work

9 **Lesson 1:** Uniform Motion
25 **Lesson 2:** Velocity
35 **Lesson 3:** Acceleration
48 **Lesson 4:** Work and Energy
58 **Section 1 Conclusion**

59 **Section 2:** Energy in Mechanical Systems

60 **Lesson 1:** Forms of Energy
72 **Lesson 2:** Potential Energy
82 **Lesson 3:** Kinetic Energy and Motion
89 **Lesson 4:** Mechanical Energy
102 **Lesson 5:** Energy Conversions
109 **Section 2 Conclusion**

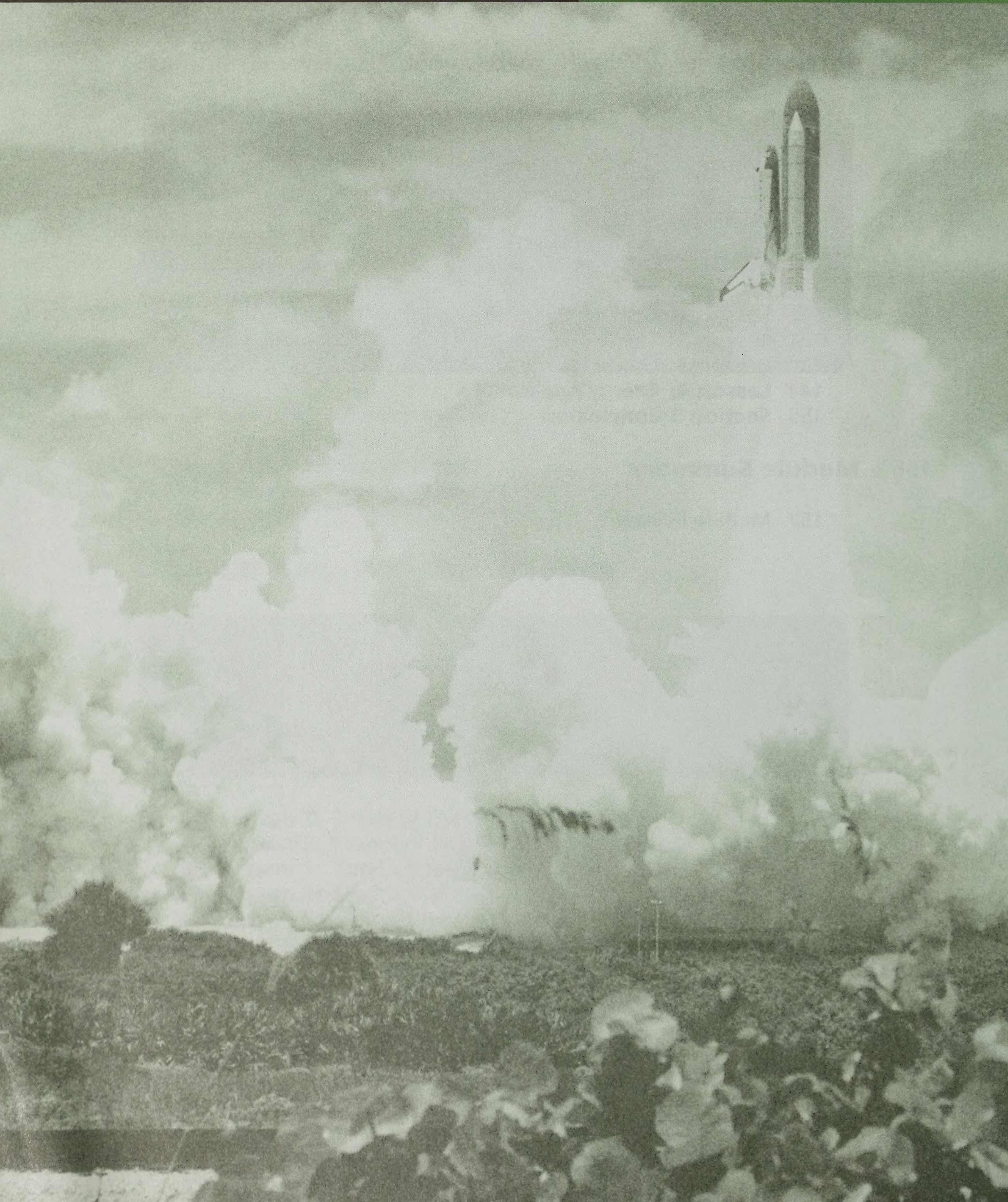
110 **Section 3:** Energy Transformations and Efficiency

111 **Lesson 1:** Laws of Thermodynamics
121 **Lesson 2:** The Development of Engine Technology
134 **Lesson 3:** Useful Energy and Efficiency
144 **Lesson 4:** Energy Applications
155 **Section 3 Conclusion**

156 **Module Summary**

157 Module Review

Module Overview



During blastoff, extremely energetic chemical reactions in the rocket engines of a space shuttle produce vast amounts of thermal energy. In the main engine, liquid hydrogen—at a frigid −253°C—is burned with oxygen. Incredibly, the burning mixture reaches 3300°C. In the solid rocket boosters, the temperature of the products are even higher. The thermal energy from the chemical reactions is used to lift the shuttle and give it the energy of motion needed to reach orbit.

The rocket engines convert thermal energy into forms of mechanical energy—the energy of height and motion. In some devices involving thermal energy, however, mechanical energy is used to move thermal energy. For example, through the rotation of a compressor pump, an air conditioner takes thermal energy from inside a warm house or car and moves it outside where it may be even warmer. To understand such energy changes, you need to understand the role of thermal energy in a variety of energy conversions.

In this module you will use theories of energy conversion and conservation to explain energy changes in natural and technological systems. You will also investigate the design and function of energy-conversion technologies.

Check out "Focus on Science and Technology" on page 123 of the textbook to see what's ahead in this module. Then read "Exploring" on page 124 for a simple and sophisticated way of harnessing energy.

Assessment

This module, Energy Flow in Technological Systems, has three section assignments. The mark distribution is as follows:

Assignment Booklet 2A	
Section 1 Assignment	35 marks
Assignment Booklet 2B	
Section 2 Assignment	48 marks
Assignment Booklet 2C	
Section 3 Assignment	40 marks
TOTAL	**123 marks**

Be sure to check with your teacher if this mark allocation is valid for you. Some teachers may include other reviews and assignments for additional assessment.

Energy Flow in Technological Systems

Section 1 Motion and Work

Section 2 Energy in Mechanical Systems

Section 3 Energy Transformations and Efficiency

Motion and Work

When you ride a bicycle, you do work when pedalling up a hill or against the wind. You get a sense that you've been working by breathing more deeply and feeling your muscles tiring.

You need to know the scientific definition of *work* in order to understand energy conversions in natural and technological systems. However, a scientific definition of *work* requires you to quantitatively represent motion in terms of position, speed, velocity, and acceleration.

In this section you will describe and graph various types of motion. You will apply the concepts of distance, displacement, speed, velocity, and acceleration to provide a complete picture of the motion of an object. You will also investigate the effect of forces on motion.

Turn to page 126 of the textbook and read the introduction to Unit B 1.0. Note the key concepts and learning outcomes listed. They provide a brief overview of what you will cover in this section.

Lesson 1

Uniform Motion

motion: a changing of position of an object relative to a reference point

uniform motion: motion in a straight line at a constant speed

Motion is everywhere—people walking along a sidewalk, kids playing at recess, cars driving down a highway . . . the list is endless. **Uniform motion** is motion in a straight line at a constant speed. Driving 100 km/h down a highway without changing speed is one example of uniform motion.

Often, people enjoy drinking a pop, hot chocolate, or some other sort of beverage while driving or riding in a vehicle, especially over long distances. Doing so in a vehicle travelling at uniform motion is easy; but try drinking these beverages in a vehicle that isn't travelling at uniform motion. It's not easy! Sudden stops and starts cause a person's drink to spill over the edges. So, next time you're in a vehicle drinking a pop or a hot chocolate, know that it's uniform motion that is allowing you to enjoy your beverage without spilling.

A speedometer shows you exactly how fast you are travelling. This gauge is one piece of equipment that can be used to describe motion and even uniform motion. How did people describe motion or uniform motion before speedometers?

For more information regarding the challenges of describing motion, turn to page 127 of the textbook and read the introductory paragraphs of "Motion" and the information in "Uniform Motion." For interest sake, take a look at the new technology in transportation found in Japan given in "*info*BIT."

1. Complete the following statements.

   a. An object is in motion if there is a change to an imaginary ____________ joining the object and a ____________ point.

   b. An object is in motion if this imaginary ____________ changes in length or ____________.

   c. An object is in ____________ motion if the ____________ of the imaginary ____________ changes at a constant rate and its ____________ stays the same.

Check Check your answers with those on page 19.

average speed: the distance travelled in a specified time

The speedometer of a vehicle shows the speed of the vehicle. The needle of a speedometer moves up and down during a typical trip, because it is showing the instantaneous speed—the speed of the vehicle at a particular instant. Because the speed during a typical trip varies, the **average speed** for the trip is more meaningful than noting various instantaneous speeds.

Turn to page 128 of the textbook and read "Average Speed" and "Using Formulas to Analyze Average Speed." Work through Example Problem B1.1 carefully.

2. a. Using the expressions v, Δt, and Δd, write the equation for average speed.

   b. Using the terms *time elapsed*, *distance travelled*, and *average speed*, write a word equation for average speed.

3. Answer question 1 of "Practice Problems" on page 128 of the textbook.

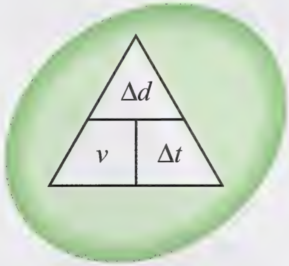
Check Check your answers with those on page 19.

Did You Know?

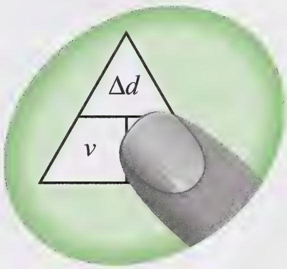
The symbol Δ is the Greek letter *delta*. This letter is used to represent a change in something. For example, Δt is read as "delta *t*" and means "change in time" (also referred to as elapsed time).

The variables in the formula for average speed may have to be rearranged to solve different problems involving motion. Look ahead to questions 2 and 3 of "Practice Problems" on page 128 of the textbook. Question 2 asks for the elapsed time, and question 3 asks for the distanced travelled. For these questions, the formula for average speed will have to be rearranged accordingly.

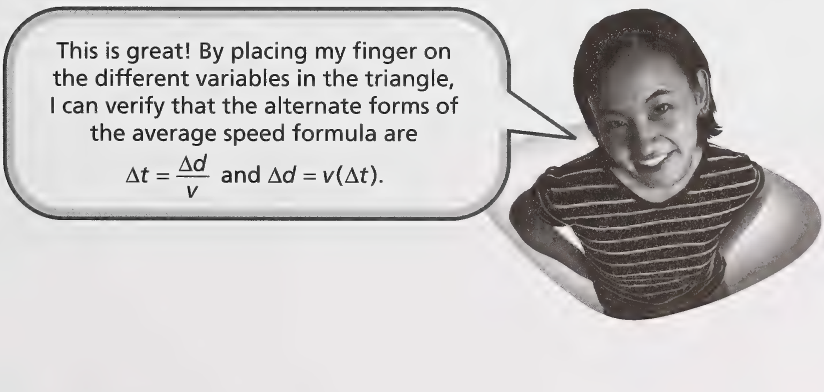
To help you rearrange the basic formula for average speed, use a triangle. That is, place the variables in a triangle according to their orientation in the formula $v = \frac{\Delta d}{\Delta t}$.



Now, you can easily see the mathematical relationships among the variables. Simply put your finger over the variable you want to determine. You will see that the other variables will be in the right orientation.



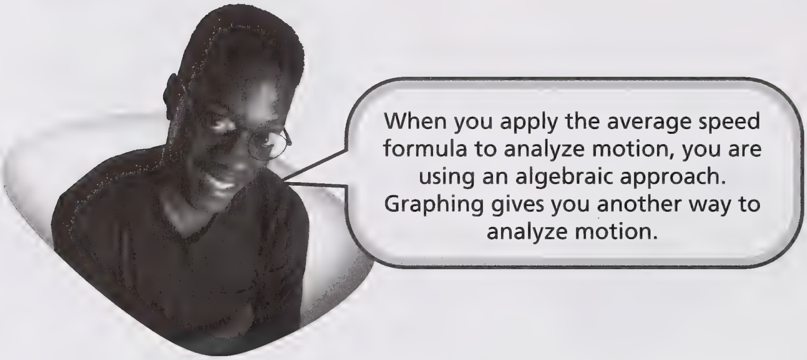
For example, suppose you want to solve for time elapsed. Put your finger over the Δt. Notice the up-and-down orientation of distance travelled, Δd, and average speed, v. This up-and-down orientation shows that you must divide Δd by v to find Δt.



4. Answer questions 2 and 3 of “Practice Problems” on page 128 of the textbook.

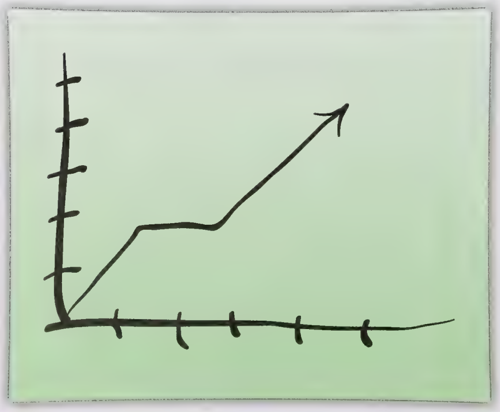
5. The speed limit on Canadian highways is given in kilometres per hour. In the scientific study of motion, speed is often given in metres per second (m/s). Convert 100 km/h into metres per second.

Check Check your answers with those on page 20.



A graph in which distance is the dependent variable and time is the independent variable is called a distance–time graph. For uniform motion, such a graph is a straight line and the slope has a special significance.

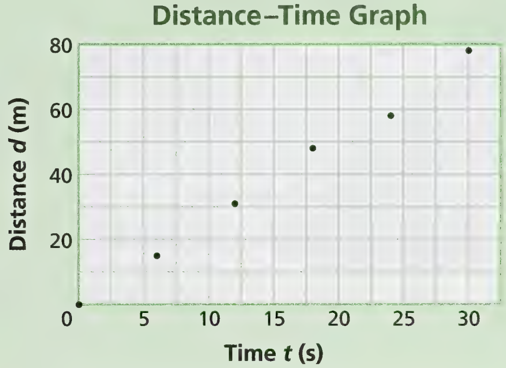
Turn to pages 128 to 130 of the textbook and read “Using Graphs to Analyze Speed” and “Plotting a Distance–Time Graph.” Work through Example Problem B1.2 carefully.



The textbook shows that the slope of a distance–time graph is equal to speed. But what happens when the data is not quite linear? Consider the following example.

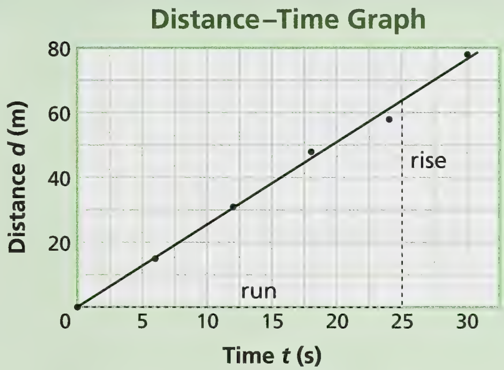
Example 1.1

The following distance–time graph shows the motion of an object. Determine the object's average speed.



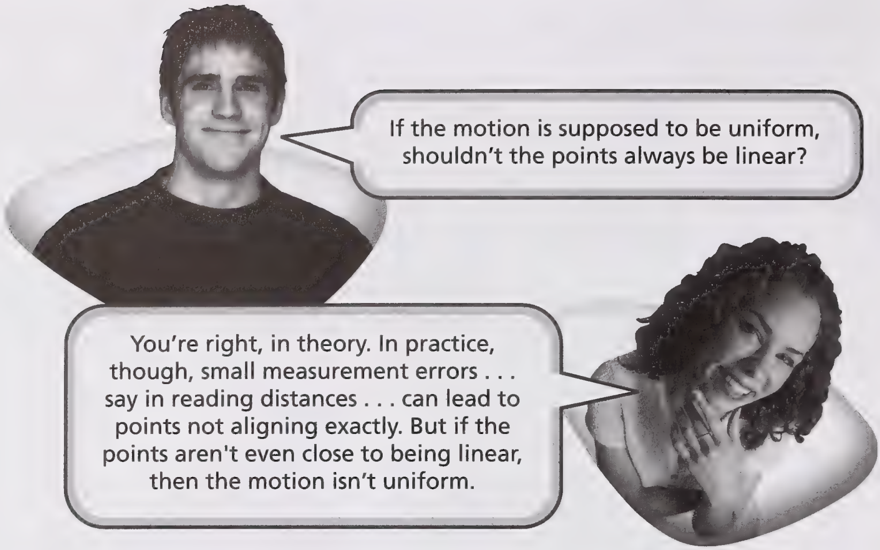
Solution

When data is not precisely linear, use a line of best fit to determine the average speed. The slope of the line of best fit corresponds to the average speed.



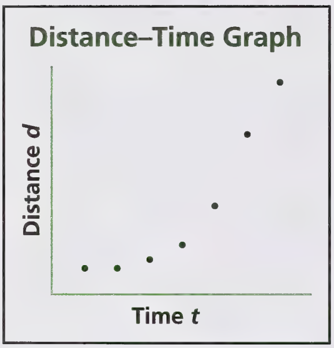
$$
\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}} \\
&= \frac{\Delta d}{\Delta t} \\
&= \frac{64\ \text{m} - 0\ \text{m}}{25\ \text{s} - 0\ \text{s}} \\
&= \frac{64\ \text{m}}{25\ \text{s}} \\
&= 2.6\ \text{m/s}
\end{aligned}
$$

Since slope is equal to speed, the object's average speed is 2.6 m/s.

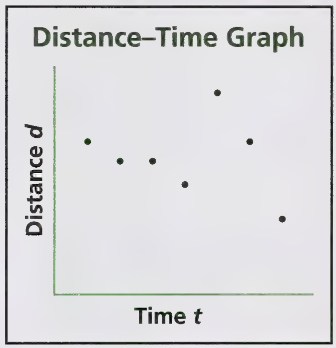


6. Which of the following distance–time graphs is most likely describing uniform motion? Explain your answer.

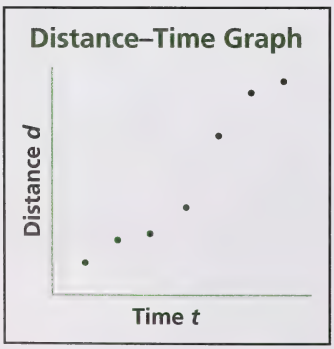
A.



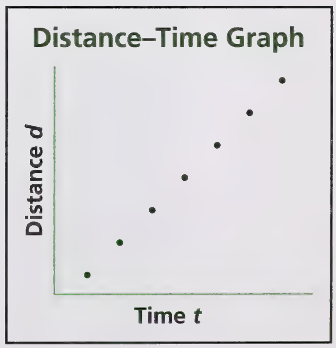
B.



C.

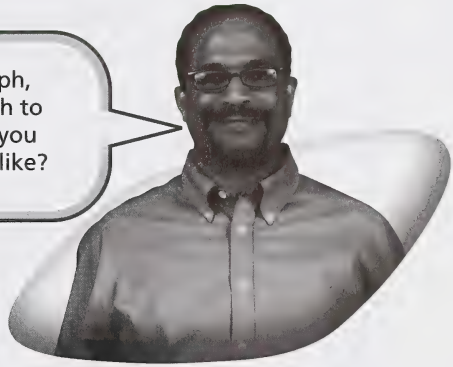


D.



7. Answer question 4 of "Practice Problem" on page 130 of the textbook. Feel free to use a spreadsheet program to draw the graph.

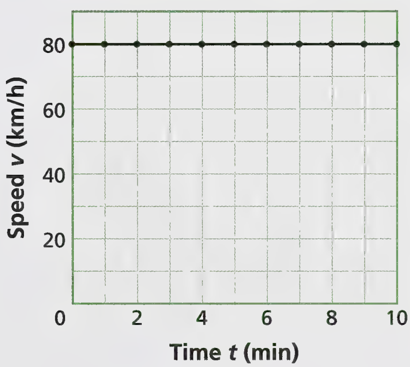
Check Check your answers with those on page 20.



Recall that a car driving down a straight, level road at exactly the same speed is moving with uniform motion. For example, suppose you noted the speed to be 80 km/h for every minute for ten minutes. Your speed–time data and its graph would look as follows:

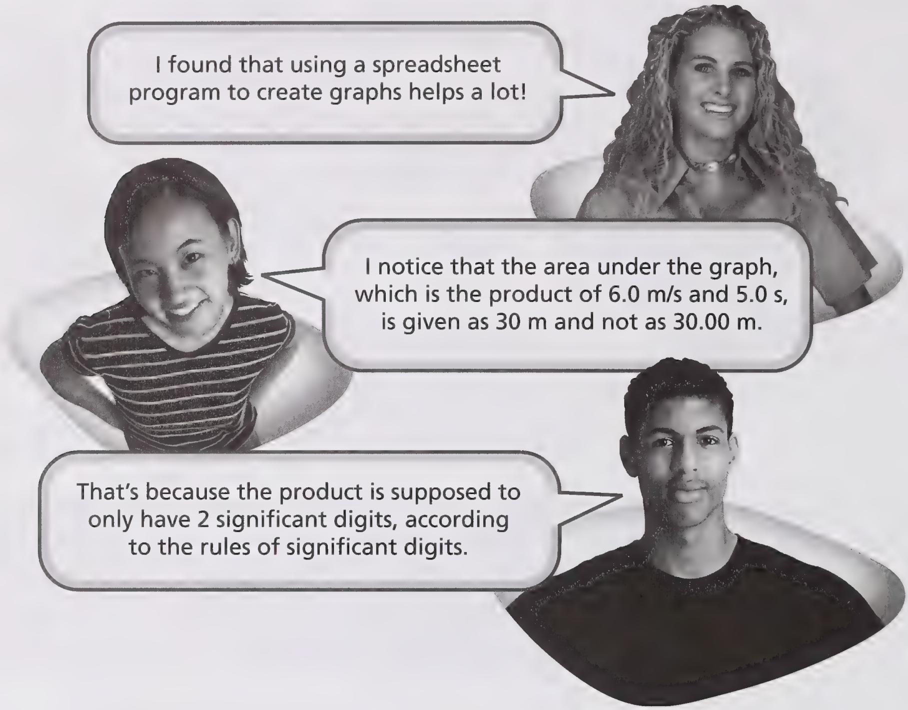
Time (min)	0	1	2	3	4	5	6	7	8	9	10
Speed (km/h)	80	80	80	80	80	80	80	80	80	80	80

Speed–Time Graph



The speed–time graph is horizontal and, therefore, has a slope of zero. The slope of the speed–time graph corresponds to the rate $\frac{\Delta v}{\Delta t}$. This rate is known as acceleration. An object moving with uniform motion is not accelerating—its acceleration is $0\ m/s^2$. (You will study acceleration in more detail later in this module.)

Turn to page 131 of the textbook and read "Plotting a Speed–Time Graph." You will analyze the motion of a boat moving with uniform motion. Look for the meaning of the area under the speed–time graph. Then work through Example Problem B1.3 on pages 132 and 133. Note how the answers are given in the proper number of significant digits.



How you display the results of a calculation depends on the data you are working with. To review the rules, read "Calculations with Significant Digits" on pages 467 and 468 of the textbook.

8. Answer questions 1, 2.a., 2.c., and 3.a. of "Skill Practice: Using Significant Digits" on page 132 of the textbook.

9. Answer question 5 of "Practice Problem" on page 133 of the textbook. Express numerical values according to the rules of significant digits.

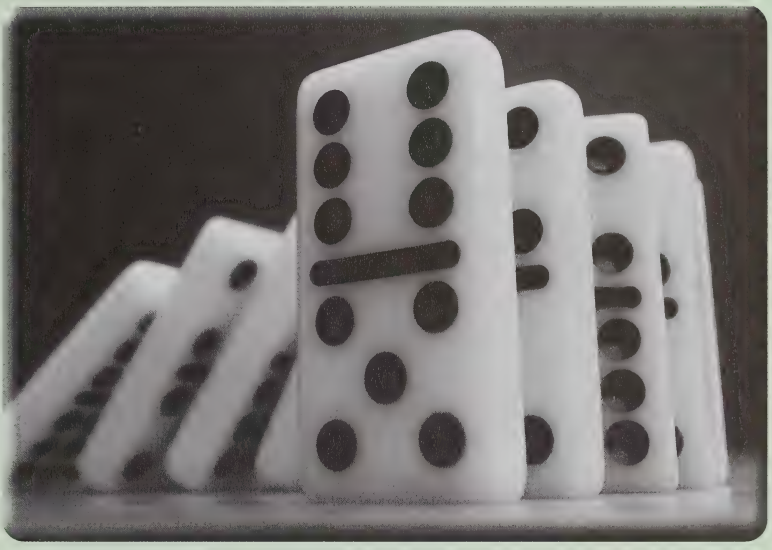
Check Check your answers with those on pages 21 and 22.

Dominoes can be lined up so that one domino falling over causes the next one to fall over and so on. In a long row of dominoes falling, the apparent motion of the ripple can be surprisingly fast. Is this motion uniform? Perform the next activity to find out.

Inquiry Lab

Studying Uniform Motion

Read the entire activity on pages 134 and 135 of the textbook.



If you have the materials and equipment listed and five people with stopwatches to help you, do **Part A**. If you do not have these resources, do **Part B**.

Part A

Follow the steps of procedure carefully. **Hint:** Let the distance be the manipulated variable and time elapsed be the responding variable.

10. Complete the table shown on page 134 of the textbook with your observations.

11. Answer the following on page 135 of the textbook. If possible, use a spreadsheet program to graph your data.

    a. questions 2 to 5 of "Analyzing and Interpreting"
    b. question 13 of "Forming Conclusions"

Check Check your answers with those on pages 22 and 23.

Part B

The following table shows the results obtained by a group of Science 10 students. Use this table to answer question 11 in Part A.

Distance *d* (cm)	Time Elapsed *t* (s)
0.00	0.00
50.00	0.73
100.00	0.88
150.00	1.45
200.00	1.77
250.00	2.57

Looking Back

You have now completed all the concepts for this lesson. You used data, formulas, and graphs to describe uniform motion.

12. Answer questions 4, 5, 6, 11, and 16 of "Check and Reflect" on pages 135 and 136 of the textbook.

Check Check your answers with those on pages 23 and 24.

Go to ... Go to pages 1 to 4 of Assignment Booklet 2A and answer questions 1 to 7.

Glossary

average speed: the distance travelled in a specified time

motion: a changing of position of an object relative to a reference point

An object is in motion when an imaginary line joining the object and a reference point changes in length or direction.

uniform motion: motion in a straight line at a constant speed

Suggested Answers

1. a. An object is in motion if there is a change to an imaginary **line** joining the object and a **reference** point.

   b. An object is in motion if this imaginary **line** changes in length or **direction**.

   c. An object is in **uniform** motion if the **length** of the imaginary **line** changes at a constant rate and its **direction** stays the same.

2. a. $v = \frac{\Delta d}{\Delta t}$ b. $\text{average speed} = \frac{\text{distance travelled}}{\text{time elapsed}}$

3. **Textbook question 1 of "Practice Problems," p. 128**

   1. $$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{4.0\times10^{6}\ \text{m}}{3.6\times10^{4}\ \text{s}} \\ &= 1.1\times10^{2}\ \text{m/s} \leftarrow \text{2 significant digits} \end{aligned}$$

   The average speed of the tsunami is 1.1×10^{2} m/s.

4. **Textbook questions 2 and 3 of "Practice Problems," p. 128**

2.
$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ \Delta t &= \frac{\Delta d}{v} \\ &= \frac{4.00 \times 10^7 \text{ m}}{694 \text{ m/s}} \\ &= 5.76 \times 10^4 \text{ s} \leftarrow \text{3 significant digits} \end{aligned}$$

It would take the Concorde 5.76×10^4 s to fly around the world. (This is about 16 h.)

3.
$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ \Delta d &= v(\Delta t) \\ &= (6.9 \text{ m/s})(4.0 \text{ s}) \\ &= 28 \text{ m} \leftarrow \text{2 significant digits} \end{aligned}$$

The train travelled 28 m.

5. $\Delta d = 100$ km $= 1.00 \times 10^5$ m $\Delta t = 1.00$ h $= 3.60 \times 10^3$ s

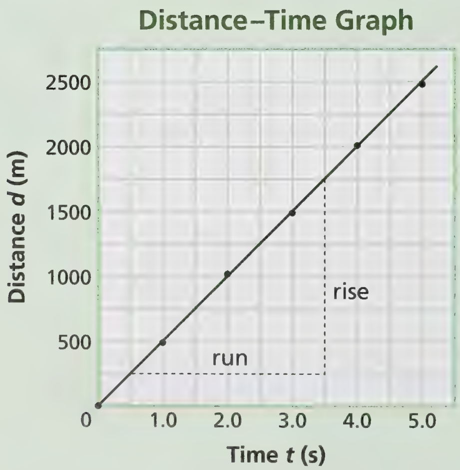
$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{1.00 \times 10^5 \text{ m}}{3.60 \times 10^3 \text{ s}} \\ &= 27.8 \text{ m/s} \end{aligned}$$

Note: Assume 3 significant digits for both distance and time since 100 km/h shows 3 significant digits.

6. Graph D is most likely describing uniform motion. The points on this graph are closer to an imaginary line than any of the others.

7. **Textbook question 4 of "Practice Problem," p. 130**

4. a. and b.



$$\begin{aligned} \text{slope} &= \frac{\text{rise}}{\text{run}} \\ &= \frac{\Delta d}{\Delta t} \\ &= \frac{1750 \text{ m} - 250 \text{ m}}{3.5 \text{ s} - 0.5 \text{ s}} \\ &= \frac{1500 \text{ m}}{3.0 \text{ s}} \\ &= 5.0 \times 10^2 \text{ m/s} \end{aligned}$$

c. The slope of the graph represents average speed.

8. **Textbook questions 1, 2.a., 2.c., and 3.a. of "Skill Practice: Using Significant Digits," p. 132**

1. a. 5 b. 6 c. 5 d. 2 e. 2

2. a. $3.20 \text{ cm} + 2.1 \text{ cm} = 5.30 \text{ cm}$
$= 5.3 \text{ cm}$

c. $3.20 \text{ km} \times 1.11 \text{ km} = 3.552 \text{ km}^2$
$= 3.55 \text{ km}^2$

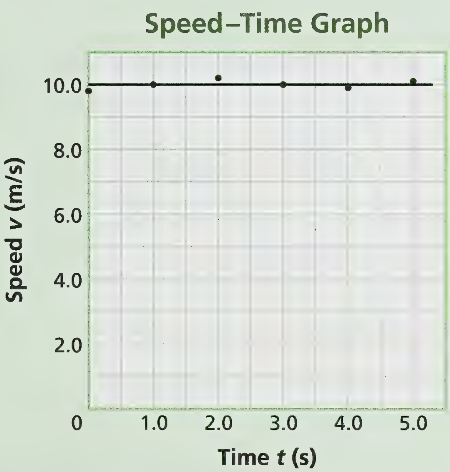
3. a. $0.002\ 21 \div (1.006 + 2.23) = 0.002\ 21 \div 3.236$
$= 6.83 \times 10^{-4}$

Note: The calculator displays $6.829\ 419\ 036 \times 10^{-4}$. Rule 3 of the rules for performing mathematical operations (on page 468 of the textbook) states that you carry all digits through to the final result without rounding. Then the final answer should be rounded to the same number of significant digits as the quantity with the fewest significant digits in the original data. In this case, 3 significant digits was the fewest in the original data. So, the final answer is rounded to 3 significant digits, 6.83×10^{-4}.

Also, note that Rule 3 is a simplified approach to evaluating expressions involving several mathematical operations. A more appropriate way of rounding lengthy calculations will be dealt with in future courses.

9. **Textbook question 5 of "Practice Problem," p. 133**

5. a. and b.



$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{10.0 \text{ m/s} - 10.0 \text{ m/s}}{3.5 \text{ s} - 1.5 \text{ s}} = \frac{0.0 \text{ m/s}}{2.0 \text{ s}} = 0.0 \text{ m/s}^2$$

The slope of the line is 0.0 m/s^2. When the slope of a speed–time graph is 0 m/s^2, the motion is uniform.

c. area = length × width

$$\begin{aligned} &= (v)(\Delta t) \\ &= (10.0 \text{ m/s})(5.0 \text{ s}) \\ &= 50 \text{ m} \end{aligned}$$

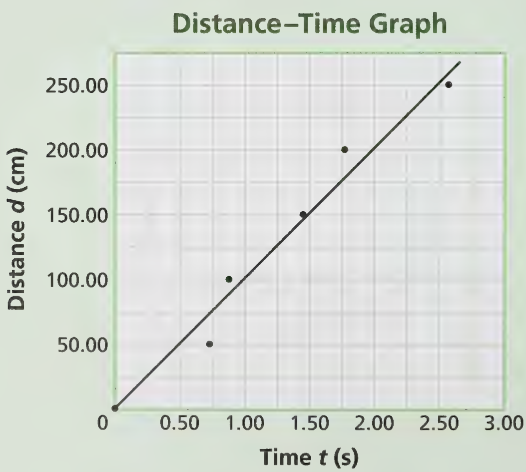
This area represents the distance travelled, 50 m.

10. Answers will vary. Sample data is given.

Distance d (cm)	Time Elapsed t (s)
0.00	0.00
50.00	0.73
100.00	0.88
150.00	1.45
200.00	1.77
250.00	2.57

11. a. **Textbook questions 2 to 5 of "Analyzing and Interpreting," p. 135**

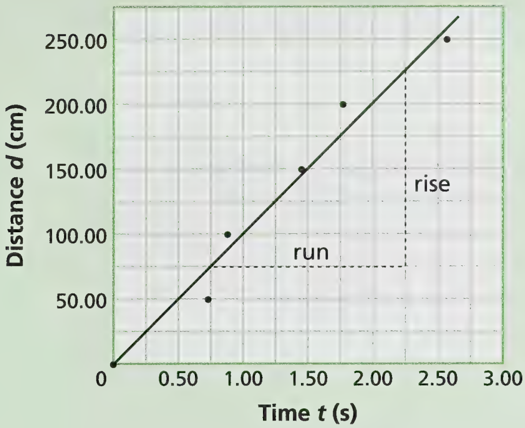
2. Graphs will vary. The following graph is based on the sample data given in the answer to question 10.



3. The line of best fit is linear (a straight line).

4. Because the line of best fit is linear, uniform motion is depicted.

5. **Distance–Time Graph**



$$
\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}} \\
&= \frac{\Delta d}{\Delta t} \\
&= \frac{225.00\ \text{cm} - 75.00\ \text{cm}}{2.25\ \text{s} - 0.75\ \text{s}} \\
&= \frac{150.00\ \text{cm}}{1.50\ \text{s}} \\
&= 1.0 \times 10^{2}\ \text{cm/s}
\end{aligned}
$$

The slope of the line of best fit is 1.0×10^2 cm/s. This value represents the average speed of the falling dominoes.

b. **Textbook question 13 of "Forming Conclusions," p. 135**

13. The data on the distance–time graph is linear (a straight line) with a positive slope. This indicates that the apparent motion of the falling dominoes is uniform.

12. **Textbook questions 4, 5, 6, 11, and 16 of "Check and Reflect," pp. 135 and 136**

4. a. You can determine speed from the slope of a distance–time graph.

   b. You can determine acceleration (a change in speed during a time interval) from the slope of a speed–time graph.

   c. You can determine the distance travelled from the area under the line of a speed–time graph.

5. The first horizontal segment shows uniform motion of the object. The second horizontal segment shows the object at rest some distance away from the starting point.

6. The first horizontal line segment indicates an object moving with uniform motion over the time interval. The second horizontal line segment shows the object moving with uniform motion over the time interval but at a lesser speed than during the first time interval.

11. $$v = \frac{\Delta d}{\Delta t}$$

$$\begin{aligned} \Delta t &= \frac{\Delta d}{v} \\ &= \frac{30.0 \text{ km}}{6.00 \text{ km/h}} \\ &= 5.00 \text{ h} \quad \leftarrow \text{3 significant digits} \end{aligned}$$

It will take the bird 5.00 h to travel 30.0 km.

16. $$\begin{aligned} \Delta d &= 15.0 \text{ m} + 12.0 \text{ m} \\ &= 27.0 \text{ m} \end{aligned}$$

$$\begin{aligned} \Delta t &= 5.00 \text{ s} + 10.00 \text{ s} \\ &= 15.00 \text{ s} \end{aligned}$$

$$\begin{aligned} v &= \frac{\Delta d}{\Delta t} \\ &= \frac{27.0 \text{ m}}{15.00 \text{ s}} \\ &= 1.80 \text{ m/s} \quad \leftarrow \text{3 significant digits} \end{aligned}$$

The average speed of the person is 1.80 m/s.

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Lesson 2

Velocity

scalar quantity: a quantity consisting of magnitude only, not direction

velocity: the speed and direction of an object

vector quantity: a quantity consisiting of magnitude and direction

Imagine you're a pilot flying from Calgary to Vancouver. In order to know that you are going to get to your destination and get there at a certain time, you need to be aware of both the speed and direction of the airplane's motion. You may be travelling at the right speed; but if you head in the wrong direction, you might end up in the wrong province. Not only would this be embarrassing as a professional pilot, but you would most likely lose your job over mistakes like this.

A pilot always needs to know the speed and direction of the airplane. In Lesson 1 you examined speed—a **scalar quantity**. The quantity that indicates both speed and direction is called **velocity**. Velocity is a **vector quantity**.

Turn to page 137 of the textbook and read the introductory paragraph of "Velocity" and the information in "Scalar and Vector Quantities."

1. How does the symbol for speed differ from the symbol for velocity?

Check Check your answer with the one on page 30.

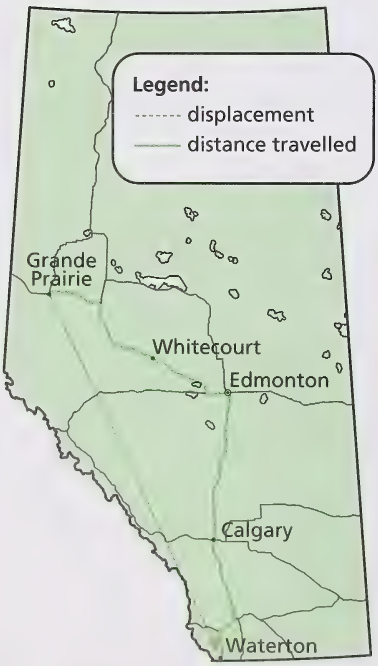
displacement: a vector quantity describing the length and direction in a straight line from the starting position to the final position

Recall from Lesson 1 that average speed was calculated by finding the distance travelled in a specified time. To calculate average velocity, **displacement** is used instead of distance travelled. Displacement has a direction attached to it. The direction of the displacement becomes the direction of the calculated average velocity.

For more about displacement and how it differs from distance travelled, turn to pages 137 and 138 of the textbook and read "Distance Travelled and Displacement."

2. From the reading, one student concluded, "The wheelchair's distance travelled might be more than the displacement but not the other way around." Is the student correct? Explain.

Check Check your answer with the one on page 30.



To see how distance travelled is different from displacement, pull out a map of Alberta. Suppose someone living in Grande Prairie drove to the Waterton townsite in Waterton National Park.

The route shows the quickest way to drive from Grande Prairie to Waterton. The distance travelled for this trip is 975 km. This can be expressed as

$$\Delta d = 975 \text{ km}$$

The resulting displacement is based on a straight line segment joining Grande Prairie and the Waterton townsite. The length of this line segment represents the magnitude of the displacement. In this case, the displacement is 750 km [S 25° E]. This can be expressed as

$$\Delta d = 750 \text{ km [S } 25° \text{ E]}.$$

The displacement from Grande Prairie was noted with a special notation in square brackets. How do you know which direction to start out with?

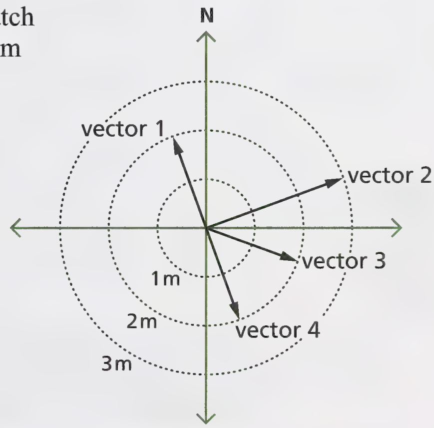
In this notation you identify the closest principal compass direction—N, S, E, or W. Then you indicate the number of degrees and direction you have to turn off this compass direction.

How do you read the notation 750 km [S 25° E]?

It is read as 750 km, 25° east of south.

3. Use the diagram on the right to match each vector with its description from the following list. You may find a protractor helpful.

    - 3 m [S 20° E]
    - 3 m [E 20° N]
    - 2 m [S 20° E]
    - 2 m [S 20° W]
    - 2 m [N 20° W]
    - 2 m [E 20° S]



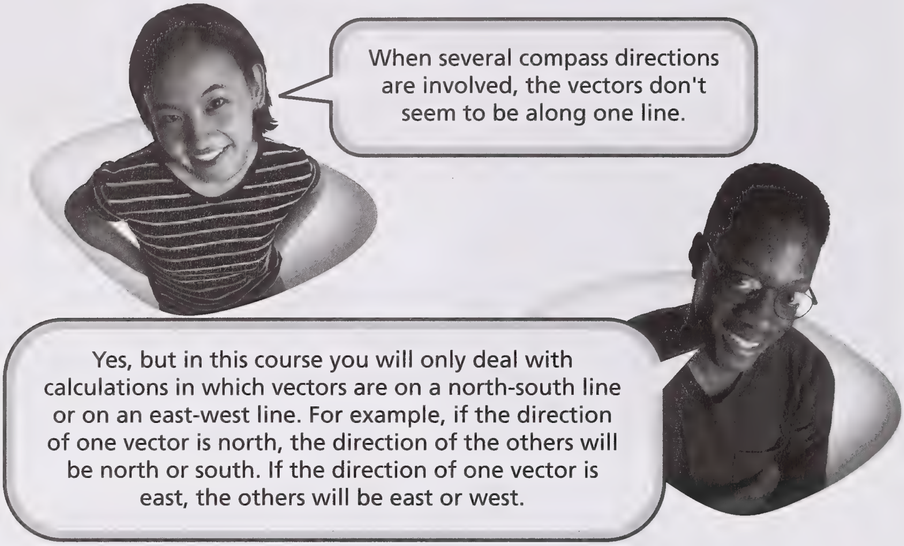
Check Check your answer with the one on page 30.

Going Further

There are other ways of indicating the direction of vectors. Turn to pages 139 and 140 of the textbook and read “How to Identify Vector Directions.”

Throughout this course, you will be performing calculations involving vectors that are along a straight line in either of two opposite directions—a positive direction or negative direction.

The direction of vectors along a straight line may be designated simply as positive or negative, up or down, or left or right.



The restriction of vectors to those that are on one straight line keeps calculations with vectors simple.

Turn to page 141 of the textbook and read “Speed and Velocity” and “Using Formulas to Analyze Average Velocity.” Work through Example Problem B1.6 carefully. You will see how vector displacement and average velocity are related.

Note: For a vector with a magnitude of zero, you don’t have to show a direction.

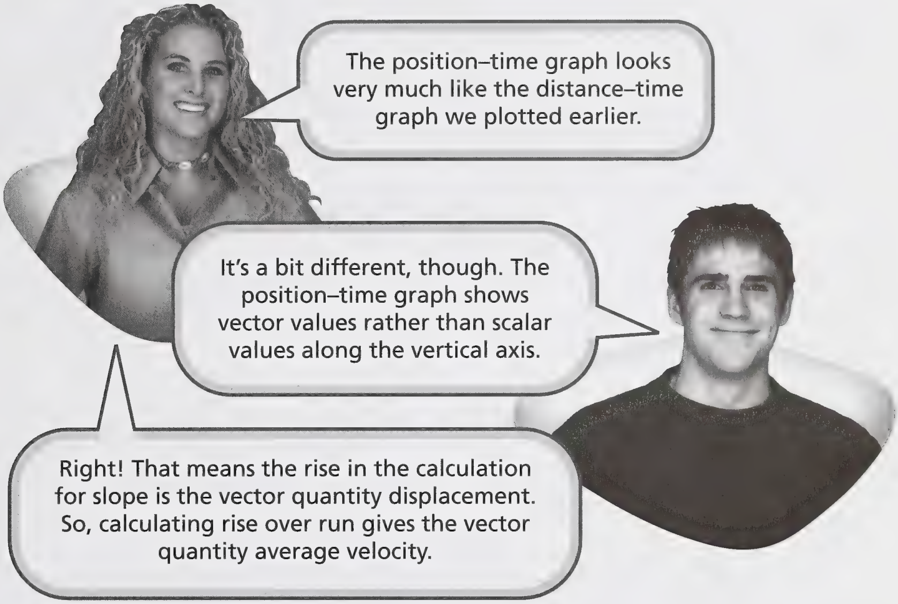
4. Answer questions 8 and 9 of “Practice Problems” on page 141 of the textbook.

Check Check your answers with those on pages 30 and 31.

position: a vector quantity describing the location of a point relative to a reference point

Previously, you’ve determined average speed by graphing distance versus time. Similarly, you can determine average velocity by graphing **position** versus time.

Turn to pages 142 to 144 of the textbook and read "Using Graphs to Analyze Average Velocity." Work through Example Problem B1.7 carefully.



5. Answer question 11 of "Practice Problem" on page 143 of the textbook. Again, use a spreadsheet program if you can.

Check your answers with those on page 31.

Looking Back

You have just completed the concepts for this lesson. You used the concepts of scalar and vector quantities to distinguish between distance travelled and displacement and between speed and velocity.

6. Answer questions 5, 6, and 8 of "Check and Reflect" on page 145 of the textbook.

Check your answers with those on pages 32 to 34.

Go to pages 5 to 7 of Assignment Booklet 2A and answer questions 8 to 15.

Glossary

displacement: a vector quantity describing the length and direction in a straight line from the starting position to the final position

position: a vector quantity describing the location of a point relative to a reference point

scalar quantity: a quantity consisting of magnitude only, not direction

vector quantity: a quantity consisting of magnitude and direction

velocity: the speed and direction of an object

Suggested Answers

1. The symbol for speed, v, does not include a vector symbol (an arrow above the v) like the symbol for velocity, $\vec{v}$.

2. Displacement is based on the shortest path between the initial and final positions. The distance travelled can be more than the displacement because the path travelled is not necessarily the shortest path from beginning to end.

   Displacement cannot be more than the distance travelled. Otherwise, the path considered to be the shortest will be longer than another path. This is a contradiction.

   > **Note:** When you use the word *more* to make comparisons involving vector quantities, you are basing the comparison on the magnitudes of the vector quantities. Directions are ignored.

3. vector 1 = 2 m [N 20° W]
   vector 2 = 3 m [E 20° N]
   vector 3 = 2 m [E 20° S]
   vector 4 = 2 m [S 20° E]

4. **Textbook questions 8 and 9 of "Practice Problems," p. 141**

   8. a. $$\begin{aligned}\Delta\vec{d} &= 10.0\ \text{m}[\text{E}] + 12.0\ \text{m}[\text{E}]\\ &= 22.0\ \text{m}[\text{E}]\end{aligned}$$

      The displacement of the student is 22.0 m [E].

b. $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$

$$\begin{aligned}
&= \frac{22.0\ \text{m}[\text{E}]}{7.00\ \text{s} + 8.00\ \text{s}}\\
&= \frac{22.0\ \text{m}[\text{E}]}{15.00\ \text{s}}\\
&= 1.47\ \text{m/s}[\text{E}] \quad \leftarrow \text{3 significant digits}
\end{aligned}$$

The average velocity of the student is about 1.47 m/s [E].

9. $\vec{v} = \dfrac{\Delta\vec{d}}{\Delta t}$

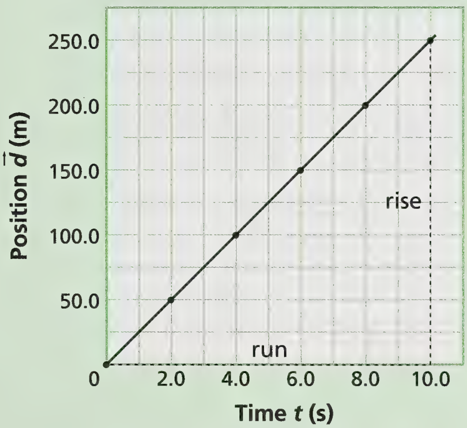
$$\begin{aligned}
\Delta\vec{d} &= \vec{v}(\Delta t)\\
&= (8.00\ \text{m/s}[\text{N}])(14.0\ \text{s})\\
&= 112\ \text{m}[\text{N}] \quad \leftarrow \text{3 significant digits}
\end{aligned}$$

The displacement of the boat is 112 m [N].

5. **Textbook question 11 of "Practice Problem," p. 143**

11. a. and b. The magnitude of the average velocity is equal to the slope of the line of best fit.

Position–Time Graph



$$\begin{aligned}
\text{slope} &= \frac{\text{rise}}{\text{run}}\\
&= \frac{\vec{d}_f - \vec{d}_i}{t_f - t_i}\\
&= \frac{250\ \text{m}[\text{E}] - 0\ \text{m}}{10.0\ \text{s} - 0\ \text{s}}\\
&= \frac{250\ \text{m}[\text{E}]}{10.0\ \text{s}}\\
&= 25.0\ \text{m/s}[\text{E}]
\end{aligned}$$

The average velocity is 25.0 m/s [E].

6. **Textbook questions 5, 6, and 8 of "Check and Reflect," p. 145**

5. a. $$\begin{aligned}\Delta d &= \Delta d_1 + \Delta d_2\\ &= 10.0\text{ m} + 15.0\text{ m}\\ &= 25.0\text{ m}\end{aligned}$$

   The distance the ball travelled is 25.0 m.

   b. Let north be the positive direction and south be the negative direction.

   $$\begin{aligned}\Delta\vec{d} &= \Delta\vec{d}_1 + \Delta\vec{d}_2\\ &= 10.0\text{ m}[\text{S}] + 15.0\text{ m}[\text{N}]\\ &= (-10.0\text{ m}) + (+15.0\text{ m})\\ &= +5.0\text{ m}\\ &= 5.0\text{ m}[\text{N}]\end{aligned}$$

   The displacement of the ball is 5.0 m [N].

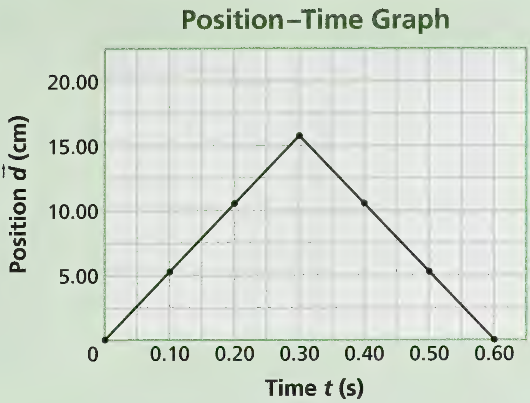
   c. $$\begin{aligned}v &= \frac{\Delta d}{\Delta t}\\ &= \frac{25.0\text{ m}}{6.00\text{ s} + 10.00\text{ s}}\\ &= \frac{25.0\text{ m}}{16.00\text{ s}}\\ &= 1.56\text{ m/s} \quad \leftarrow \text{3 significant digits}\end{aligned}$$

   The average speed of the ball is 1.56 m/s.

   d. $$\begin{aligned}\vec{v} &= \frac{\Delta\vec{d}}{\Delta t}\\ &= \frac{5.0\text{ m}[\text{N}]}{16.00\text{ s}}\\ &= 0.31\text{ m/s}[\text{N}] \quad \leftarrow \text{2 significant digits}\end{aligned}$$

   The average velocity of the ball is 0.31 m/s [N].

6. a.



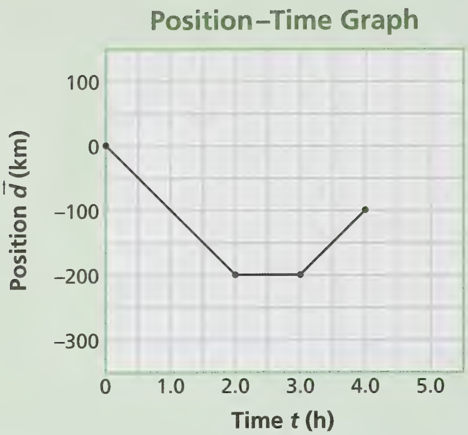
b. There are two slopes.

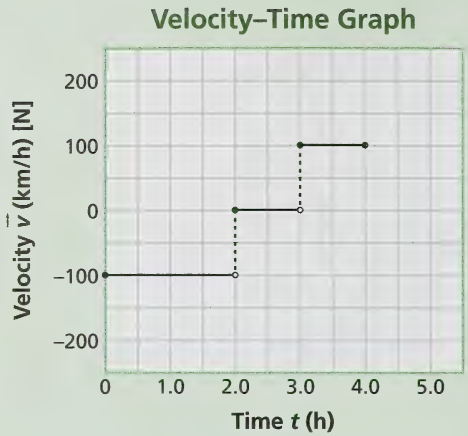
$$\begin{aligned}\text{slope}_1 &= \frac{\text{rise}}{\text{run}}\\ &= \frac{\vec{d}_f - \vec{d}_i}{t_f - t_i}\\ &= \frac{15.74\ \text{cm}[\text{E}] - 0\ \text{cm}}{0.30\ \text{s} - 0\ \text{s}}\\ &= \frac{15.74\ \text{cm}[\text{E}]}{0.30\ \text{s}}\\ &= 52\ \text{cm/s}[\text{E}]\end{aligned}$$

$$\begin{aligned}\text{slope}_2 &= \frac{\text{rise}}{\text{run}}\\ &= \frac{\vec{d}_f - \vec{d}_i}{t_f - t_i}\\ &= \frac{0\ \text{cm} - 15.74\ \text{cm}[\text{E}]}{0.60\ \text{s} - 0.30\ \text{s}}\\ &= \frac{-15.74\ \text{cm}[\text{E}]}{0.30\ \text{s}}\\ &= \frac{15.74\ \text{cm}[\text{W}]}{0.30\ \text{s}}\\ &= 52\ \text{cm/s}[\text{W}]\end{aligned}$$

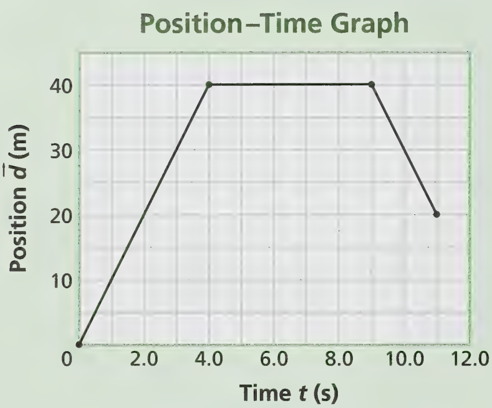
You can determine the velocity from the value of the slope.

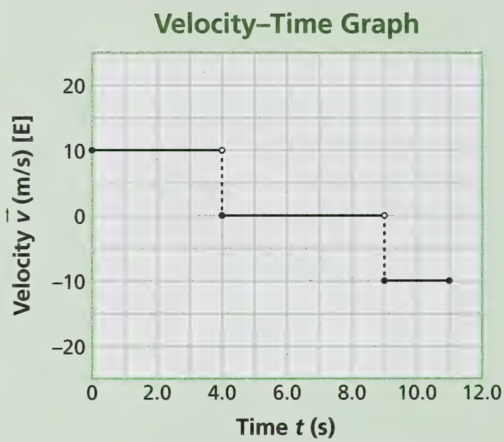
8. a.





b.





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Lesson 3

Acceleration

acceleration: a change in velocity during a specific time interval

As a passenger inside a jet airplane streaking across the sky at 850 km/h, you may hardly be aware of your velocity. As long as the airplane is in uniform motion, you may not even sense its high speed. In contrast to uniform motion, **acceleration** is easily sensed.

Turn to page 146 of the textbook and read the introductory paragraph of "Acceleration." Then continue on by reading the information in "Types of Acceleration" on pages 146 and 147. Study Figure B1.22 closely.

1. In Figure B1.22, which illustrates positive and negative acceleration, the phrase "increasing $\vec{v}$" is short for saying that the magnitude of the velocity is increasing. Now, complete the following sentence regarding "decreasing $\vec{v}$."

   When $\vec{v}$ is decreasing, the ____________ of the velocity is ____________.

2. Match each diagram with the scenarios listed. Assume that the automobile in each scenario is moving in a straight line along a level path. The positive direction is towards the front of the vehicle.

    i. The automobile is in Drive and moving forward while the gas pedal is pressed down.

    ii. The automobile is in Reverse and moving backwards while the gas pedal is pressed down.

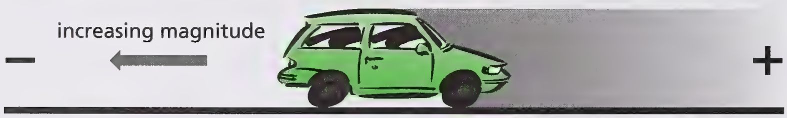
    iii. The automobile is moving backwards while the brake is being applied.

    iv. The automobile is moving forward while the brake is being applied.

a. 

b. 

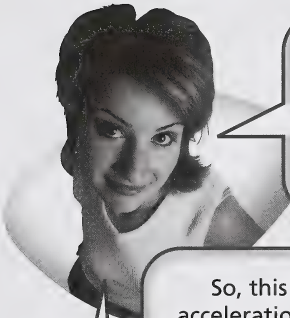
c. 

d. 

Check Check your answers with those on page 42.

The acceleration achieved by the space shuttle blastoff is astonishing. Did you know that you can study such acceleration quantitatively by using formulas and graphs?

Turn to page 147 of the textbook and read "Using Formulas and Graphs to Analyze Accelerated Motion." Work through Example Problem B1.8 carefully.



Note that the formula $a = \frac{v_f - v_i}{\Delta t}$ can be used to find the acceleration of an object. But the object's motion must remain in one direction only for this formula to work. Also, you have to think of this direction as the positive direction.

So, this formula can't be used to find the acceleration of a baseball as it goes up into the air and then back down to the ground again.

That's a good example! The ball changes direction at the top of its path. So, the formula $a = \frac{v_f - v_i}{\Delta t}$ would not apply. Fortunately, in this course you will focus on motion in one direction.

The acceleration could still come out as a negative number. That'll happen if the final velocity is less than the initial velocity.

Yes, with this formula, negative acceleration indicates that the object is slowing down.

3. Answer questions 12 and 13 of "Practice Problems" on page 147 of the textbook.

Check Check your answers with those on page 42.

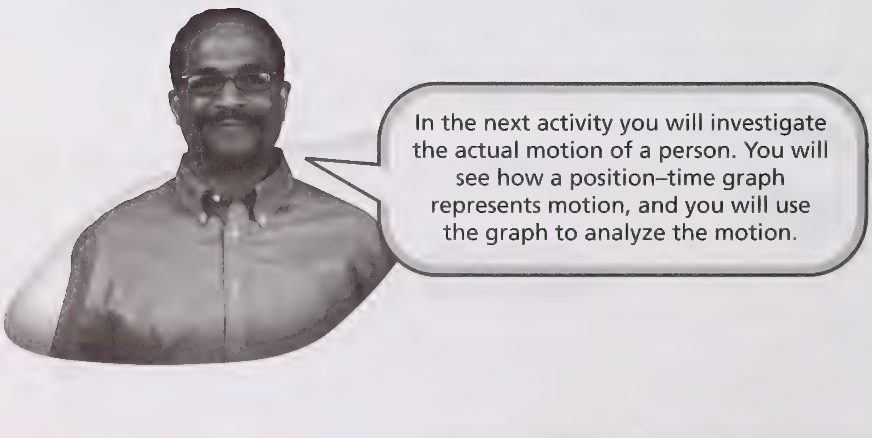
When you see the needle of a speedometer rotating clockwise, that means the vehicle—whether it be an automobile or a motorboat—is accelerating. It is no longer moving with uniform motion.

Thus far, you have seen that uniform motion is represented by a straight line sloping upwards on a position–time graph. The position–time graph of accelerated motion is not represented by a straight line on a position–time graph. It is represented by a curved line.

Turn to pages 148 and 149 of the textbook and read "Plotting a Position–Time Graph." Carefully work through Example Problem B1.9 on page 149.

4. Answer question 16 of "Practice Problem" on page 149 of the textbook.

Check Check your answers with those on page 43.



Inquiry Lab

Get in Motion!

Read the entire activity on pages 150 and 151 of the textbook.

If you have the materials and equipment listed and a partner to help you, do **Part A**. If you do not have any of the materials and equipment listed or a partner, do **Part B**.

Part A

If you have access to a motion sensor and related equipment, follow Method 1 of the procedure. If you do not have access to a motion sensor, follow Method 2 of the procedure. If you're following Method 2, you may substitute a tape measure for metre-sticks and strips of adding machine tape.

5. Graph the data. Make sure you draw a smooth curve through the data points.

6. Answer the following on page 151 of the textbook.

   a. questions 1, 2, and 3 of "Analyzing and Interpreting"
   b. question 4 of "Forming Conclusions"
   c. question 6 of "Applying and Connecting"

Check Check your answers with those on pages 43 and 44.

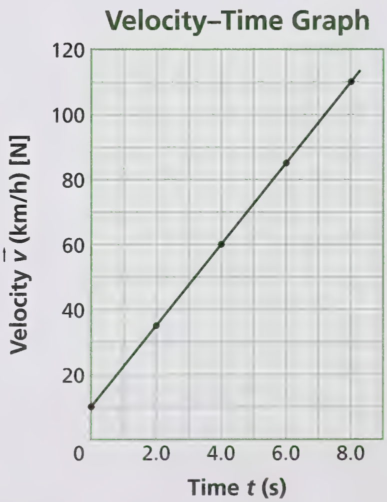
Part B

A couple of students obtained the following data after completing Method 1 of the procedure. The distances measured are all in the same direction. Let this be the positive direction. Use this information to answer questions 5 and 6 in Part A.

Time t (s)	0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
Position d (m) [+]	0.5	0.5	0.5	0.5	0.5	0.6	1.1	1.7	2.3	2.9	3.3	3.4	3.5	3.5	3.5

Suppose you are in a car moving north (a positive direction). The speedometer reading goes from 10 km/h to 110 km/h in 8 s.

Time Elapsed t (s)	Velocity $\vec{v}$ (km/h) [N]
0.0	+10
2.0	+35
4.0	+60
6.0	+85
8.0	+110



The automobile is accelerating and the velocity–time graph is linear. In the next reading you will look at other velocity–time graphs involving acceleration.

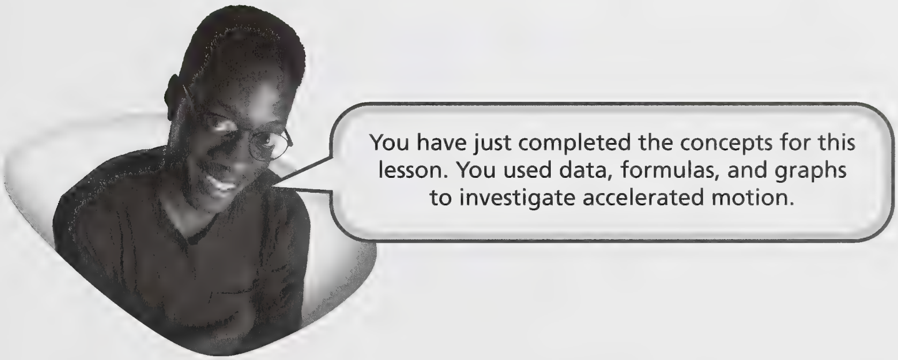
Turn to pages 152 and 153 of the textbook and read "Plotting a Velocity–Time Graph." Work through Example Problem B1.10 carefully.

Example Problem B1.10 shows three intervals in which the graph is linear. In these intervals, acceleration is constant. Acceleration only changes going from one interval to the next. You will see similar intervals of constant acceleration in the next question.

7. Answer question 17 of "Practice Problem" on page 153 of the textbook.

Check — Check your answers with those on page 45.

Looking Back



8. Answer questions 1, 3, 4, 5, and 8 of "Check and Reflect" on pages 154 of the textbook.

9. Answer question 20 of "Section Review" on page 163 of the textbook. Again, use a spreadsheet to graph the data if you wish.

Check — Check your answers with those on pages 45 to 47.

Go to ... — Go to pages 7 to 10 of Assignment Booklet 2A and answer questions 16 to 21.

Glossary

acceleration: a change in velocity during a specific time interval

Suggested Answers

1. When $\vec{v}$ is decreasing, the **magnitude** of the velocity is **decreasing**.

> **Note:** There's another way of interpreting increasing and decreasing velocity. When $\vec{v}$ is increasing, speed is increasing; when $\vec{v}$ is decreasing, speed is decreasing.

2. a. i b. iii c. iv d. ii

3. **Textbook questions 12 and 13 of "Practice Problems," p. 147**

12. $$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ &= \frac{+50 \text{ m/s} - 0 \text{ m/s}}{4.00 \text{ s}} \\ &= +13 \text{ m/s}^2 \text{ or } 13 \text{ m/s}^2 \text{ [up]} \leftarrow \text{2 significant digits}\end{aligned}$$

The acceleration of the shuttle craft is 13 m/s^2 upwards.

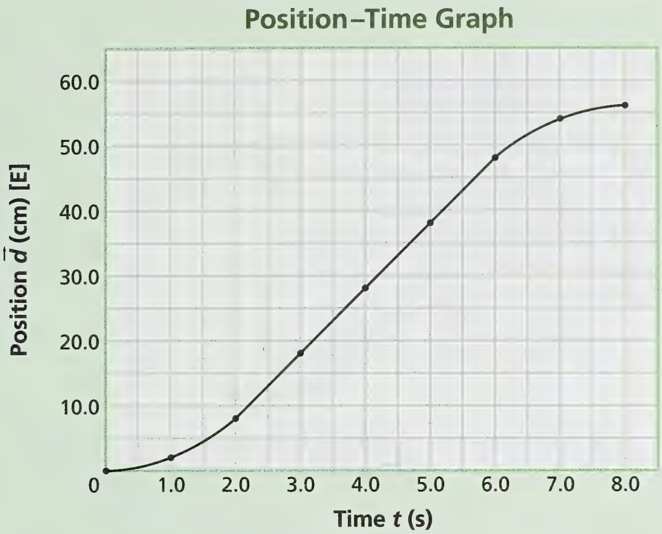
13. Let the initial direction, which is towards the mitt, be the positive direction.

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_f - \vec{v}_i}{\Delta t} \\ &= \frac{0.0 \text{ m/s} - (+25.0 \text{ m/s})}{0.500 \text{ s}} \\ &= -50.0 \text{ m/s}^2\end{aligned}$$

The magnitude of the ball's acceleration is 50.0 m/s^2.

4. **Textbook question 16 of "Practice Problem," p. 149**

16. a.

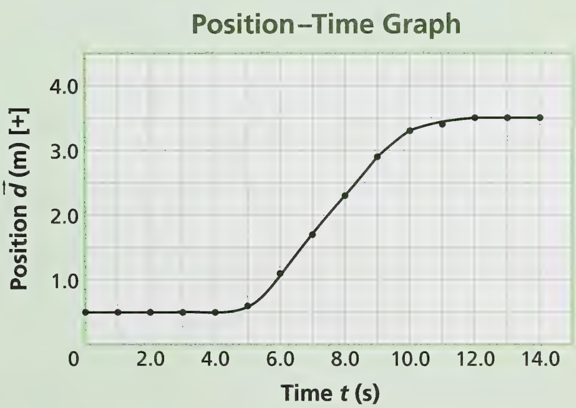


b. i. Between $t = 0.0$ s and $t = 3.0$ s, there is accelerated motion. This is shown by the curve of the graph.

ii. Between $t = 3.0$ s and $t = 6.0$ s, there is uniform motion. The graph is linear during this time interval.

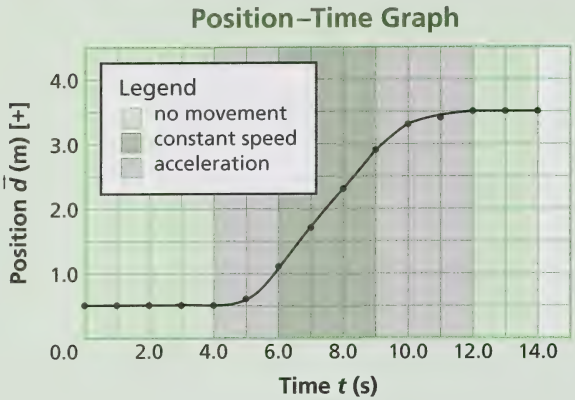
iii. Between $t = 6.0$ s and $t = 8.0$ s, the graph is curved with a decreasing slope. This indicates a negative acceleration.

5. Graphs will vary. A sample graph is given.



6. a. **Textbook questions 1, 2, and 3 of "Analyzing and Interpreting," p. 151**

1.



2. The no-movement portions of the graph are horizontal; the contant-speed portion of the graph is linear with a positive slope; and the acceleration portions of the graph are curved (either upward to indicate positive acceleration or downward to indicate negative acceleration).

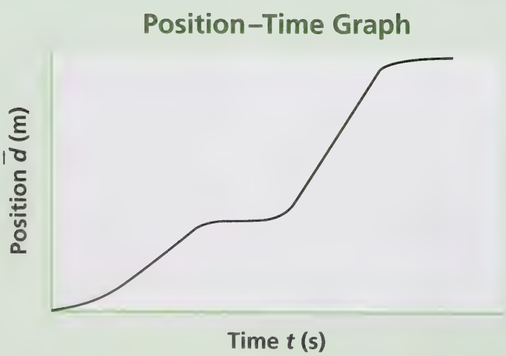
3. The slope of the graph at any given time indicates the speed at that time.

b. **Textbook question 4 of "Forming Conclusions," p. 151**

4. The movement of an object can be depicted in three different ways on a position–time graph. When the object is standing still, the line is horizontal over the time interval. When the object is moving with uniform motion, the line is linear with a positive slope over the time interval. When the object is accelerating, the line curves (is non-linear) over the time interval.

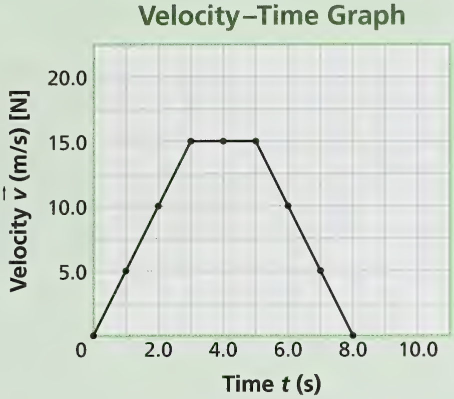
c. **Textbook question 6 of "Applying and Connecting," p. 151**

6.



7. **Textbook question 17 of "Practice Problem," p. 153**

17. a.



b. i. Between $t = 0$ s and $t = 3.0$ s, the object is accelerating.

ii. Between $t = 3.0$ s and $t = 5.0$ s, the object is moving with uniform motion. The graph is horizontal during this interval.

iii. Between $t = 5.0$ s and $t = 8.0$ s, the object is undergoing a negative acceleration. The graph has a negative slope during this interval.

8. **Textbook questions 1, 3, 4, 5, and 8 of "Check and Reflect," p. 154**

1. According to the usual practice, east is considered to be the positive direction and west the negative direction.

a. positive acceleration

The speed increases while the object continues in a positive direction.

b. negative acceleration

The speed decreases while the object continues in a positive direction.

c. negative acceleration

The speed increases while the object continues in a negative direction.

d. positive acceleration

The speed decreases while the object is moving in a negative direction.

Note: If you had trouble with this question, it may be helpful to think about which way you would have to nudge the object to make it accelerate in the manner described. In other words, consider the force needed to make the object accelerate. The direction of this force indicates the sign (positive/negative) of the acceleration. If the direction of the force is in a positive direction, the acceleration is considered positive; if the force is in a negative direction, the acceleration is negative.

The following solutions are based on considering the force needed to make the acceleration happen:

a. positive acceleration

The force would have to be applied towards the east—the positive direction.

b. negative acceleration

The force would have to be applied towards the west—the negative direction.

c. negative acceleration

The force would have to be applied towards the west—the negative direction.

d. positive acceleration

The force would have to be applied towards the east—the positive direction.

3. Let the forward direction (toward the front of the train) be the positive direction. Then the backward direction (toward the back of the train) is the negative direction.

   a. The train could be exhibiting positive acceleration by gaining speed while moving forward or by slowing down while moving backward.

   b. The train could be exhibiting negative acceleration by slowing down while moving forward or by speeding up while moving backward.

4. a.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$(\vec{a})(\Delta t) = \vec{v}_f - \vec{v}_i$$
$$\Delta t = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}}$$

b.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$\vec{v}_f - \vec{v}_i = (\vec{a})(\Delta t)$$
$$\vec{v}_f = (\vec{a})(\Delta t) + \vec{v}_i$$

5. Let north be the positive direction.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$= \frac{0 \text{ m/s} - (+15 \text{ m/s})}{3.0 \text{ s}}$$
$$= -5.0 \text{ m/s}^2 \text{ or } 5.0 \text{ m/s}^2 \text{ [S]}$$

The acceleration of the bus is 5.0 m/s^2 [S].

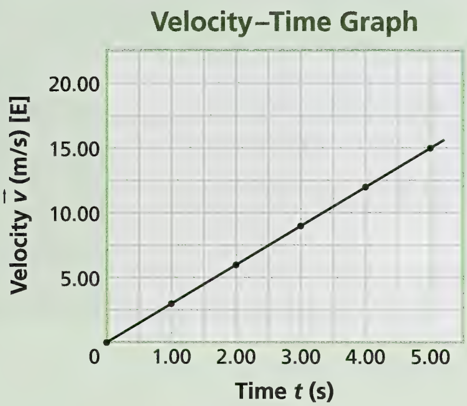
8. Let north be positive.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$
$$\vec{v}_f - \vec{v}_i = \vec{a}(\Delta t)$$
$$\vec{v}_f = \vec{a}(\Delta t) + \vec{v}_i$$
$$= (+1.30 \text{ m/s}^2)(6.00 \text{ s}) + 0 \text{ m/s}^2$$
$$= +7.80 \text{ m/s or } 7.80 \text{ m/s [N]}$$

The final velocity of the object is 7.80 m/s [N].

9. **Textbook question 20 of "Section Review," p. 163**

20. a.



b. The velocity–time graph has a linear, positive slope over the time interval. This indicates that the object is undergoing a positive, constant acceleration.

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Lesson 4

Work and Energy

Do you enjoy curling, whether it be playing or simply watching? Have you ever tried to throw a curling rock? It is massive. It takes lots of force to get the rock started. But once moving, no additional force needs to be applied to the rock; it continues on its own.

work: the transfer of energy from one object or system to another when a force is applied over a distance

energy: the ability to do work

The investigation of the relation between force and motion led to the concepts of **work** and **energy**. The concepts of work and energy helped explain why objects move and change position.

Turn to pages 156 and 157 of the textbook and read "Force."

1. What is needed for an object to speed up or slow down?

2. What happens to the speed of an object if there is no unbalanced force acting on the object?

Check Check your answers with those on page 53.

The force applied to an object and the distance through which the force is applied affects the motion (or condition) of the object. The effect is based on the product of force and distance. This product corresponds to the quantity of work involved.

$$\text{work} = \text{force} \times \text{distance}$$
$$W = Fd$$

Turn to page 157 of the textbook and read "Work."

3. The reading indicates three conditions required for work to be done on an object. Refer to Figure B1.38 of a student carrying a pack. The student is not doing "scientific" work on the pack. Which of the three conditions is not met?

Check Check your answer with the one on page 53.

Climbing to the top of a mountain or hill certainly requires a lot of work—you exert a force along your direction of motion up the hill. To get to the top of the mountain or hill, would you do more work going up the mountain in the most direct manner or going along a roundabout trail?

The next activity deals with a similar question: "Which involves more work—getting an object up to a certain height along a ramp or lifting the object directly to the same height?"

Inquiry Lab

Doing Work

Read the entire activity on pages 158 and 159 of the textbook.

Instead of a block of wood, you can substitute any wheeled object, such as a toy car. The object should weigh between 2 N and 10 N. Pick an object you can easily attach a string to. The spring scale should have a capacity of 10 N. You may also use a metric measuring tape rather than a metre-stick. Masking tape is useful for marking ramp lengths.

If you have access to the materials and equipment listed (or substitutes) and a partner to help you, do **Part A**. If you do not have access to the materials and equipment or a partner, do **Part B**.

Part A

Carefully follow the steps of the procedure.

4. Answer the following. These questions refer to steps 2, 3, and 7 of the procedure.

   a. What is the vertical height of the inclined plane at the 0.50-m mark?
   b. How much does the block weigh (in N)?
   c. Complete the data table outlined in step 7 of the procedure.

work input: the work done on a machine being used to move a load

work output: the work done by a machine on a load

Think of work input as the work you do in getting the object up the ramp and work output as the useful work done by the ramp. The purpose of the ramp is simply to lift the object to a certain height. So, the output work is equal to the work you have to do in lifting the object directly to the height of the ramp without using the ramp at all.

5. Answer the following on page 159 of the textbook.

   a. questions 1 to 9 of "Analyzing and Interpreting"
   b. questions 10 and 12 of "Forming Conclusions"

Check Check your answers with those on pages 53 and 54.

Part B

A couple of students who completed Part A recorded the following data:

- The vertical height at the 0.50-m mark is 0.36 m.
- The weight of the object is 8.1 N.

Distance d (m)	Force F (N)
0.00	6.7
0.10	6.5
0.20	6.6
0.30	6.7
0.40	6.7
0.50	6.6

Use this data to answer question 5 in Part A.

In the preceding Inquiry Lab you used a graph and a formula to determine the quantity of work done. You also compared work input and work output of a ramp. For further discussion of work, turn to pages 159 and 160 of the textbook and read "The Relationship Between Work Output and Work Input." Work through Example Problem B1.11 carefully.

6. Answer questions 18 and 19 of "Practice Problems" on page 160 of the textbook.

Check Check your answers with those on page 55.

Going Further

The unit used for work and energy is the joule (J). To find out the origin of this unit's name, complete the "*re*SEARCH" activity in the margin on page 159 of the textbook. Start your research by visiting the following website:

http://www.scienceman.com/science10

Select "Unit B: HotLinks," and scroll down to Text Pages 159–160. There you will find a list of websites with information about the joule.

When a weight is lifted upwards, the weight gains energy. The gain in energy is due to the work done by the lifter. Work and energy are always closely related. Sometimes doing work on an object—such as pushing a curling rock through a distance—gives the object motion. The object in motion thereby gains a special form of energy, called kinetic energy. So, even when work simply places an object in motion, energy is involved.

Turn to page 160 of the textbook and read "Energy." Work through Example Problem B1.12 carefully.

7. Answer question 20 of "Practice Problem" on page 160 of the textbook.

Check Check your answer with the one on page 55.

Looking Back

You have just completed the concepts for this lesson. You investigated force, work, and changes in energy.

8. Answer questions 2, 4, 6, 8, and 10 of "Check and Reflect" on page 161 of the textbook.

9. Answer questions 6, 7, 21, 23, and 24 of "Section Review" on pages 162 and 163 of the textbook.

Check Check your answers with those on pages 55 to 57.

Go to ... Go to pages 10 and 11 of Assignment Booklet 2A and answer questions 22 to 28.

Glossary

energy: the ability to do work

work: the transfer of energy from one object or system to another when a force is applied over a distance

The quantity of work is equal to the product of force and distance ($W = Fd$).

work input: the work done on a machine being used to move a load

work output: the work done by a machine on a load

Work output is equal to the work needed to move a load directly without a machine.

Suggested Answers

1. For an object to speed up or slow down, an unbalanced force must act on the object. This force must be in the same direction as or in the opposite direction of the object's motion.

2. If there is no unbalanced force acting on the object, the object's speed remains the same. **Note:** With no unbalanced force, the direction of motion will not change either.

3. Condition 3 is not met. The force and the distance the pack travels are not in the same direction.

4. Data will vary. Sample data is given.

   a. The vertical height at the 0.50-m mark is 0.36 m.

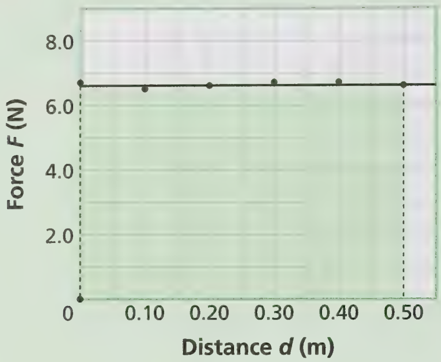
   b. The object weighs 8.1 N.

   c.

Distance d (m)	Force F (N)
0.00	6.7
0.10	6.5
0.20	6.6
0.30	6.7
0.40	6.7
0.50	6.6

5. a. **Textbook questions 1 to 9 of "Analyzing and Interpreting," p. 159**

1. to 4. Pulling an Object Up a Ramp



5. $$\begin{aligned}\text{area} &= (\text{length along } y\text{-axis})(\text{width along } x\text{-axis}) \\ &= (6.6\text{ N})(0.50\text{ m}) \\ &= 3.3\text{ N}\bullet\text{m or } 3.3\text{ J}\end{aligned}$$

Note: The line of best fit crosses the vertical axis closer to 6.6 than 6.7. So, assume 6.6 in this case.

6. The area represents the work done in pulling the object up the ramp.

7. The area under the graph is a work input because it was the work on the machine being used to move the object. (The machine being used to move the object was the inclined plane.)

8. $$\begin{aligned}W &= Fd \\ &= (8.1\text{ N})(0.36\text{ m}) \\ &= 2.9\text{ J} \leftarrow \text{2 significant digits}\end{aligned}$$

   The work done in lifting the object directly is 2.9 J.

9. The work done in lifting the object is equivalent to the work done by the machine. Therefore, this value (2.9 J) is a work output.

b. **Textbook questions 10 and 12 of "Forming Conclusions," p. 159**

10. The values of work input and work output are not equal.

12. The values are not the same. The work input includes work done in overcoming the force of friction.

6. **Textbook questions 18 and 19 of "Practice Problems," p. 160**

18. $$\begin{aligned} W &= Fd \\ &= \left(6.50\times10^{3}\ \text{N}\right)\left(150\ \text{m}\right) \\ &= 9.75\times10^{5}\ \text{J} \end{aligned}$$

    The work done by the tugboat is 9.75×10^{5} J.

19. $$\begin{aligned} W &= Fd \\ F &= \frac{W}{d} \\ &= \frac{2.2\times10^{4}\ \text{J}}{9.5\ \text{m}} \\ &= 2.3\times10^{3}\ \text{N} \end{aligned}$$

    The average force exerted was 2.3×10^{3} N.

7. **Textbook question 20 of "Practice Problem," p. 160**

20. $$\begin{aligned} \Delta E &= W \\ &= 2.2\times10^{4}\ \text{J} \end{aligned}$$

    The object gained 2.2×10^{4} J of energy.

8. **Textbook questions 2, 4, 6, 8, and 10 of "Check and Reflect," p. 161**

2. When work is done on an object, the object gains energy.

4. $1\ \text{N} = 1\ \text{kg}\bullet\text{m/s}^{2}$

6. a. $$\begin{aligned} W &= Fd \\ &= (98.0\ \text{N})(1.50\ \text{m}) \\ &= 147\ \text{J} \end{aligned}$$

   The work done in lifting the rock is 147 J.

   b. $$\begin{aligned} W &= Fd \\ &= (25.0\ \text{N})(2.00\ \text{m}) \\ &= 50.0\ \text{J} \end{aligned}$$

   The work done in pushing the sleigh is 50.0 J.

c. $W = Fd$

$$= (2.00\ \text{N})(0.100\ \text{m})$$
$$= 0.200\ \text{J}$$

The work done (on the kitten) by the mother cat is 0.200 J. This work done is only in lifting the kitten. The mother cat does no work in carrying the kitten.

8. The height corresponds to the distance, d, in the formula for work.

$$W = Fd$$
$$d = \frac{W}{F}$$
$$= \frac{2.00 \times 10^4\ \text{J}}{1.20 \times 10^3\ \text{N}}$$
$$= 16.7\ \text{m}$$

The machine lifted the object 16.7 m.

10. a. The rectangle representing the area under the graph has a length (along the y-axis) of 50 N and width (along the x-axis) of 100 m.

$$\text{area} = \text{length} \times \text{width}$$
$$= (50\ \text{N})(100\ \text{m})$$
$$= 5.0 \times 10^3\ \text{N•m or } 5.0 \times 10^3\ \text{J}$$

b. The area under the graph represents the amount of work done. Therefore, the work done in moving the object through the distance of 100 m is 5.0×10^3 J.

Note: If the applied force fluctuates as an object is moved through a distance, the force–distance graph will not be horizontal. The force–distance graph may be wavy. Even then the area under the graph represents the actual work done. The area-equals-work concept is useful for complicated problems.

9. **Textbook questions 6, 7, 21, 23, and 24 of "Section Review," pp. 162 and 163**

6. a. If balanced forces act on an object, the object will move with uniform motion.
   b. If unbalanced forces act on an object, the object will move with accelerated motion.

7. The work done on an object increases the energy of the object, according to the formula $\Delta E = W$. Therefore, the units of energy and work are the same.

21. Answers may vary. The directions may be considered in terms of east and west or in terms of right and left (as in the sample solution given).

    The unbalanced force $(\vec{F})$ is the sum of the two forces acting on the object.

    Let the positive direction be to the right and the negative direction be to the left.

    $$\begin{aligned}\vec{F} &= \vec{F}_1 + \vec{F}_2 \\ &= (-10\ \text{N}) + (+30\ \text{N}) \\ &= +20\ \text{N}\end{aligned}$$

    The unbalanced force is 20 N [right].

23. $$\begin{aligned}\Delta E &= W \\ &= Fd \\ &= (35\ \text{N})(3.0\ \text{m}) \\ &= 1.1\times10^{2}\ \text{J}\end{aligned}$$

    The object gains 1.1×10^{2} J of energy.

24. $$\begin{aligned}W &= Fd \\ F &= \frac{W}{d} \\ &= \frac{350\ \text{J}}{10.0\ \text{m}} \\ &= 35.0\ \text{N}\end{aligned}$$

    To move the crate, an average force of 35.0 N must be applied.

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Conclusion

In this section you came to appreciate how motion is related to work and energy. You distinguished between uniform motion and accelerated motion, and you applied formulas and graphing techniques to gain insight into the way objects move. You described speed as a scalar quantity and velocity as a vector quantity; and, later, you related the force on an object to a change in its motion and to work done on the object. You used the scientific definition of *work* to develop the concept of energy.

When you pedal a bicycle, you get a sense of doing work. This is consistent with the scientific definition of *work*. You actually do work when you apply a force on the pedals through a distance.

Energy in Mechanical Systems

Archery is a sport that requires a steady hand, a keen eye, and—believe it or not—an understanding of the science of energy and motion. To shoot an arrow, you have to draw back the string. As you draw back the string, you apply a force through a distance. The work you do is stored as energy in the flexed bow. When you release the string, the bow returns to its former shape and releases energy. The energy from the bow is converted into the arrow's energy of motion as the arrow accelerates.

When using a bow and arrow, numerous forms of energy are involved. Throughout the arrow's journey—from pulling back the bow to releasing the string to the flight of the arrow to the arrow's final resting place in the target—there are several energy conversions from one form into another that occur.

In this section you will study forms of energy and their relation to work. You will describe historical discoveries leading to the concepts of energy and energy conversion. You will also use methods to describe the quantity of different forms of energy. You will then survey a variety of forms of energy and identify energy conversions that occur in nature and in technological devices.

Turn to page 164 of the textbook and read the introduction to Unit B 2.0. Pay particular attention to the key concepts and learning outcomes listed. They provide a brief overview of what you will cover in this section.

Lesson 1

Forms of Energy

At a solar energy plant, curved mirrors are used to concentrate solar energy. The concentrated solar energy can be converted into other forms of energy, such as thermal energy and electrical energy.

There are many forms of energy. In the QuickLab that follows, you will identify a few of these forms.

QuickLab

All Kinds of Energy

Read the entire activity on page 125 of the textbook.

You won't need to make your own observations. Instead, use the following information about each station.

Station 1: A radiometer has four vanes suspended inside a glass bulb. The bulb has some of the air removed. The veins can spin freely.

The veins of a radiometer started rotating when light shined on them.

Figure 2.1: Station 1

Station 2: Turning on a flashlight illuminated surfaces in front of the flashlight.


Figure 2.2: Station 2

Station 3: The magnet picked up the piece of iron.

Station 4: The pendulum swings down and then back up the other side. The pendulum continues swinging back and forth.

Station 5: When the vinegar dripped onto the baking soda, the mixture started fizzing. Bubbles formed showing the presence of a gas.

Station 6: As the hanging mass fell to the table, it pulled the block of wood up the ramp.

Station 7: The ebonite rod picked up the bits of paper.

Station 8: The wind up car quickly moved forward.

1. Answer questions 1, 3, and 4 of "Questions" on page 125 of the textbook.

Check Check your answers with those on page 67.

The QuickLab you just completed was designed to increase your awareness of energy around you. Next, you will examine how the concept of energy developed over time. You will see that the understanding of energy depended on the development of technological devices that could produce or measure energy.

Turn to page 165 of the textbook and read the introductory paragraphs of "Forms of Energy." Continue your reading by studying the information in "Chemical Energy" and "Electrical Energy and Magnetism" on pages 165 to 167.

2. Answer questions 1, 2, and 3 of "Check and Reflect" on page 172 of the textbook.

Check Check your answers with those on pages 67 and 68.

kinetic energy: energy due to the motion of an object

gravitational potential energy: energy due to the position of an object above Earth's surface

Nuclear power plants supply about 15% of Canada's electricity. The discovery of energy from atoms' nuclei was made from a small sample of atoms. These atoms had nuclei that disintegrated on their own.

Well before the discovery of unstable nuclei, **kinetic energy** and **gravitational potential energy** were identified on the bases of direct, observable changes. To find out more about these forms of energy, turn to page 167 of the textbook and read "Nuclear and Solar Energy" and "Motion and Energy."

Insert the Science 10 Multimedia CD into your computer, and click on "Newton's Cradle." You will get a chance to see Newton's cradle in motion.

3. Answer questions 4, 5, and 8 of "Check and Reflect" on page 172 of the textbook.

4. The sum of kinetic energy and gravitational potential energy of an object has a special significance. This sum is called ____________.

Check Check your answers with those on pages 68 and 69.

While the connection between motion and energy was being explored, others were investigating the nature of heat.

Turn to page 169 of the textbook and read "Heat and Energy" and "Heat and Mechanical Energy."

thermodynamics: the study of the interrelationships between heat, work, and energy

Even before there was any formal talk of **thermodynamics**, people were applying an understanding of heat and its behaviour. For example, First Nations people "worked" a wooden drill, much like the one on the left, to produce heat.

Read "*info*BIT" on page 169 of the textbook for more on heat production.

Furthermore, First Nations people had an effective way to heat water well before the convenience offered by modern stoves and metal pots.

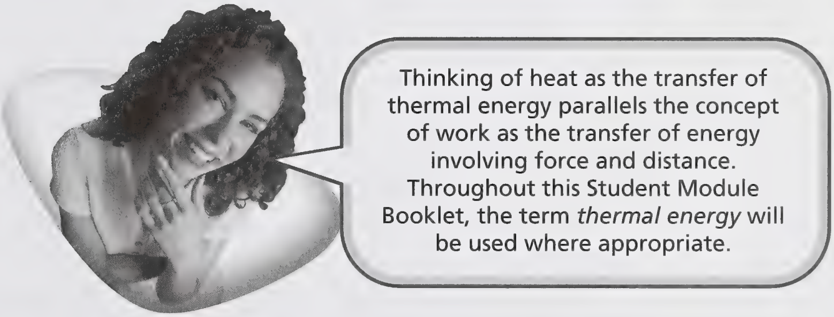
Read "*info*BIT" on page 170 of the textbook for more on the heating of water.

5. Answer question 9.b. and 9.c. of "Check and Reflect" on page 172 of the textbook. **Note:** Question 9.b. should reference Thomas Young, not James Young.

Check Check your answers with those on page 69.

Count Rumford's experiments showed a relationship between mechanical energy and heat. In the next activity you will observe this relationship using an eggbeater.

Note: Throughout the textbook the term *heat* is often used for *thermal energy*. The terms *heat* and *thermal energy* are closely related, but they are not synonymous to scientists. *Thermal energy* is the preferred scientific term for the energy possessed by a substance due to the kinetic energy of its molecules and atoms. Scientists reserve the term *heat* for reference to the **transfer** of thermal energy.



Inquiry Lab

Mechanical Energy and Heat

Read the entire activity on page 168 of the textbook.

6. State a hypothesis.

7. Identify the manipulated, responding, and controlled variables.

Check Check your answers with those on page 69.

If you have access to the materials and equipment listed, do **Part A**. If you do not have access to the materials and equipment, do **Part B**.

Part A

Follow the steps outlined in the procedure. **Be careful not to get the thermometer caught in the beaters**.

8. Complete the table given in step 1 of the procedure.
9. Answer the following on page 168 of the textbook.
   a. questions 1 to 4 of "Analyzing and Interpreting"
   b. questions 5 and 6 of "Forming Conclusions"
10. Many people turn on a fan when they find the air in a room too hot. Based on your findings, what effect does running a fan have on the air in a room? Explain.

Check Check your answers with those on pages 69 to 71.

Part B

One student completed this lab and recorded the following data. Use this data to answer questions 9 and 10 in Part A.

Time of Beating (min)	Temperature of Water (°C)
0	22.0
2	24.0
4	25.5
6	27.5
8	29.0
10	30.0

heat engine: a device that converts heat into mechanical energy

Did you know that electrical power plants give off waste energy? So do automobiles, trains, and airplanes. These technologies involve a **heat engine**, which converts heat—from the combustion of fuel—into mechanical energy. But no matter how efficient these technologies are, they give off some waste thermal energy. A French engineer by the name of Sadi Carnot determined that there's no way around this waste.

Converting mechanical energy into heat is much easier than converting heat into mechanical energy. By studying the conversion of mechanical energy into heat, J. P. Joule showed that the connection between mechanical energy and heat was much closer than previously thought.

Turn to page 170 of the textbook and read "Joule's Experiment." Study Figures B2.7 and B2.8 closely.

11. Answer question 10 of "Check and Reflect" on page 172 of the textbook.

Check your answer with the one on page 71.

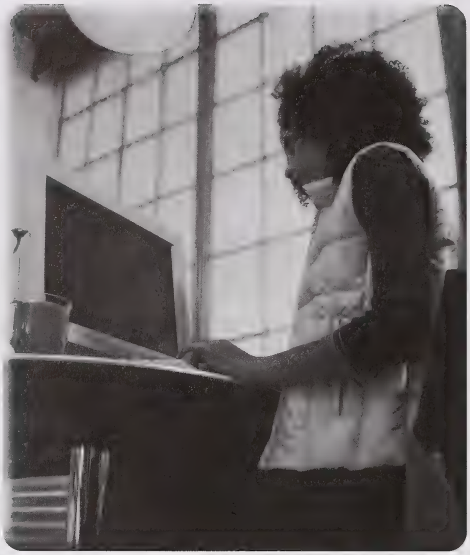
A power engineer is a person who is skilled in the management of energy conversion and utilization of technology.

Turn to page 171 of the textbook and read "Career and Profile." You will read an interview with Perry Ambrose, a power engineer who has worked at the Rossdale Generating Station in Edmonton for many years. See what it takes to work as a power engineer.

For more about preparing for a career as a power engineer, visit the website of the Northern Alberta Institute of Technology (NAIT) or the website of the Southern Alberta Institute of Technology (SAIT). These sites can be found at

http://www.nait.ca
http://www.sait.ca

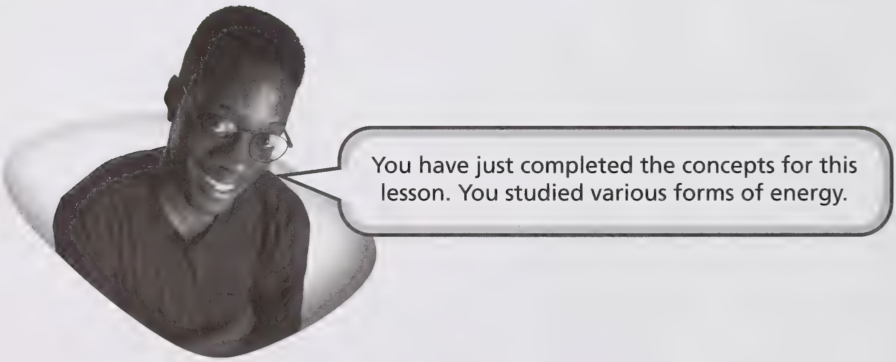
Once you are at the site, enter *power engineering technology* in the search engine. You will find helpful information and a list of contacts.



12. Answer questions 1 and 2 of "Career and Profile" on page 171 of the textbook.

Check your answers with those on page 71.

Looking Back



13. Answer questions 13 and 14 of "Check and Reflect" on page 172 of the textbook.

Check your answers with those on pages 71 and 72.

Go to pages 1 and 2 of Assignment Booklet 2B and answer questions 1 to 3.

Glossary

chemical energy: potential energy stored in the chemical bonds of compounds

gravitational potential energy: energy due to the position of an object above Earth's surface

heat engine: a device that converts heat into mechanical energy

kinetic energy: energy due to the motion of an object

nuclear energy: the potential energy stored in the nucleus of an atom

solar energy: energy due to the fusion of hydrogen nuclei on the Sun

thermodynamics: the study of the interrelationships between heat, work, and energy

Suggested Answers

1. **Textbook questions 1, 3, and 4 of "Questions," p. 125**

   1. Answers may vary. The following types of energy were present at each station:

      Station 1: light energy, radiant energy, and thermal energy
      Station 2: light energy and thermal energy
      Station 3: magnetic energy
      Station 4: mechanical energy, kinetic energy, and potential energy
      Station 5: chemical energy
      Station 6: potential energy and kinetic energy
      Station 7: static electrical energy
      Station 8: elastic or spring potential energy and kinetic energy

   3. Answers will vary. Although energy cannot be seen, evidence of mechanical energy, light energy, and thermal energy are commonly observed.

   4. Answers will vary. You may now be aware of chemical energy or thermal energy.

2. **Textbook questions 1, 2, and 3 of "Check and Reflect," p. 172**

   1. Faraday discovered that magnetism can be converted into electricity.

2. The scientists and their inventions are summarized in the following table.

Inventor/ Scientist	Invention	Type of Energy Produced	How Energy Was Produced
Oersted	primitive electric motor	mechanical energy	A current-carrying wire experienced a force when it was placed in an external magnetic field.
Faraday	generator	electrical energy	A wire was moved through a magnetic field.
Seebeck	thermoelectric device	electrical energy	The junction between two strips of different metals was heated.
Edison	light bulb	light energy and thermal energy	An electric current was made to flow through a metal filament.
Volta	battery	electrical energy	Paper layers saturated with a salt solution connected disks made of dissimilar metals.

3.

Invention	Practical Use
primitive electric motor	Electric motors are used in furnace fans, electric shavers, CD players, etc.
generator	Electric generators are used in power plants to provide electricity as a utility and in automobiles to charge the battery.
thermoelectric device	Thermoelectric devices are used in night-vision goggles; temperature sensors; and in small, portable refrigerators.
light bulb	Modern light bulbs are used in homes, businesses, arenas, etc.
battery	Batteries are used in CD players, MP3 players, hearing aids, mobility scooters, electric cars, flashlights, etc.

3. **Textbook questions 4, 5, and 8 of "Check and Reflect," p. 172**

4. In nuclear fusion, nuclei combine to form larger nuclei. In nuclear fission, nuclei split to form smaller nuclei. In both nuclear fusion and nuclear fission, large amounts of energy are released. However, nuclear fusion can release more energy than nuclear fission.

5. Early scientists thought that the source of energy in the Sun was chemical energy released through combustion. This theory was not accepted because it would have meant that the Sun would have used up its combustible materials already—it would have burned up within 5000 years of its formation.

8. Scientists of the 1600s observing Newton's cradle used the idea of *vis viva* or "living force" to explain the motion of the ball on the opposite side. They thought that *vis viva* was transmitted through the stationary balls to the ball at the opposite side. This movement of *vis viva* caused the ball at the opposite side to rise.

4. The sum of kinetic energy and gravitational potential energy of an object has a special significance. This sum is called **mechanical energy**.

5. **Textbook question 9.b. and 9.c. of "Check and Reflect," p. 172**

9. b. Thomas Young's ideas led to the modern definition of energy. He hypothesized that mechanical energy combined both kinetic energy and potential energy. Mechanical energy in a system was related to the amount work the system could do.

   c. Joseph Black thought of thermal energy as a fluid, which he called *caloric*. He stated that caloric always flows out of hot objects into cold objects.

6. Answers will vary. A sample hypothesis is given.

   The amount of mechanical energy applied to a system is proportional to the heat gained because mechanical energy will convert into thermal energy.

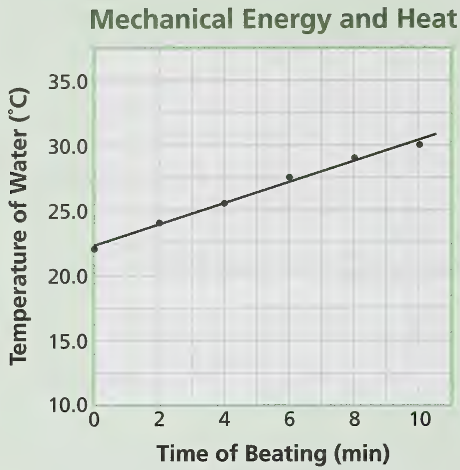
7. Time of beating is the manipulated variable, and temperature of the water is the responding variable. The controlled variables are the amount of water and the initial temperature of the water.

8. Data will vary. Sample data is given.

Time of Beating (min)	Temperature of Water (°C)
0	22.0
2	24.0
4	25.5
6	27.5
8	29.0
10	30.0

9. a. **Textbook questions 1 to 4 of "Analyzing and Interpreting," p. 168**

1. Answers will vary. The following graph is based on the data given in the answer to question 8.



2. The line of best fit is linear (a straight line) with a positive slope. This indicates that the temperature of the water increases the longer you beat the water.

3. The amount of mechanical energy applied to the system corresponds to the time (or duration) of beating. **Note:** Here, mechanical energy is used to refer to the energy of a moving part of a machine—in this case the energy of the rotating beater.

4. The temperature corresponds most closely to the thermal energy (heat) gained by the system.

b. **Textbook questions 5 and 6 of "Forming Conclusions," p. 168**

5. The graph shows that the amount of mechanical energy applied to the system is proportional to the thermal energy (heat) gained by the system.

6. Answers will vary depending on the original hypothesis. A sample answer is given.

   The experiment supports the hypothesis that the amount of mechanical energy applied to the system is proportional to the heat (thermal energy) gained by the system. This is because mechanical energy is converted into thermal energy. There will be very little "heat" loss because the temperature of the water does not become much hotter than its surroundings.

10. Answers may vary.

    Running a fan likely raises the temperature in a room. The mechanical energy used to turn the fan is converted into thermal energy of the air. An increase in the thermal energy of the air comes with a rise in air temperature.

    > **Note:** You may feel cooler in front of a fan because the evaporation of perspiration from your skin and clothing is quicker. The fan may actually cool the room if cooler outside air is drawn in.

11. **Textbook questions 10 of "Check and Reflect," p. 172**

    10. Using a device like the one shown in Figure B2.7, Joule showed that mechanical energy of falling masses could be converted into thermal energy (heat) in water. The mechanical energy of the masses (as indicated by their height above the ground) is the manipulated variable, and the thermal energy of the water (as indicated by its temperature) is the responding variable.

        As the height of the masses decreases, the temperature of the water increases. As the masses fall, they lose mechanical energy at the same rate the stirred water gains thermal energy. This showed that thermal energy (heat) can be produced from mechanical energy.

12. **Textbook questions 1 and 2 of "Career and Profile," p. 171**

    1. You need to complete a power engineering program at NAIT, SAIT, or any other recognized technical institute.

    2. Answers will vary. You may find the problem-solving nature of the work appealing. Or you may be interested in maintaining large mechanical systems.

13. **Textbook questions 13 and 14 of "Check and Reflect," p. 172**

    13. Answers will vary. Sample answers are given.

        a. **chemical energy:** battery, cell, and automobile
        b. **light energy:** solar panel and solar calculator
        c. **thermal energy (heat):** steam turbine, heat radiator in a house, and infrared camera
        d. **electrical energy:** TV, radio, electric motor, and computer
        e. **magnetic energy:** compass and electric generator

    14. Answers will vary. Sample answers are given.

        a. **chemical energy:** Hoffman apparatus and rechargeable battery (during recharging)

        > **Note:** Green plants produce chemical energy during photosynthesis.

        b. **light energy:** light bulb

c. **thermal energy (heat):** iron, furnace, and toaster
d. **electrical energy:** generator and solar panel
e. **magnetic energy:** transformer and electromagnet

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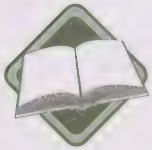
Lesson 2

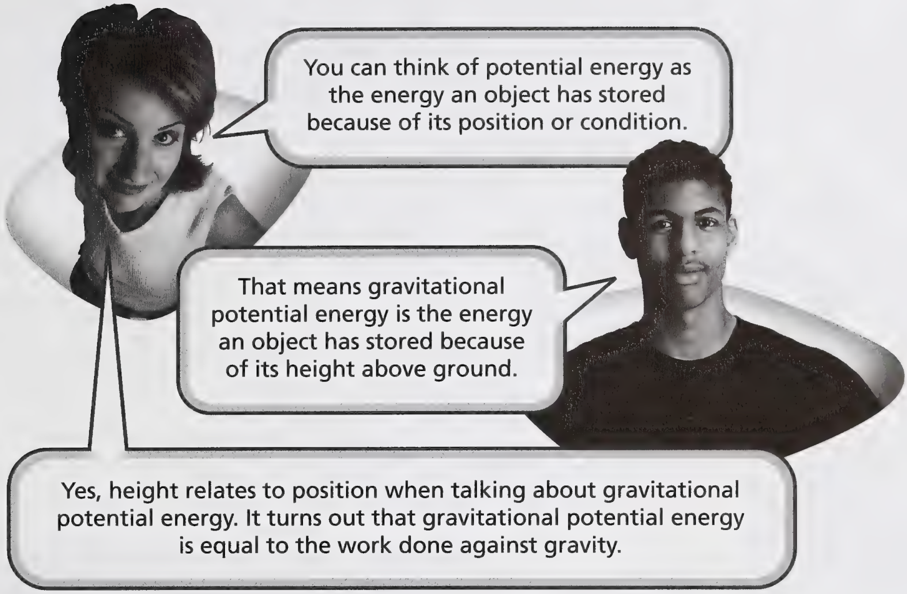
Potential Energy

potential energy: energy stored and held in readiness to do work

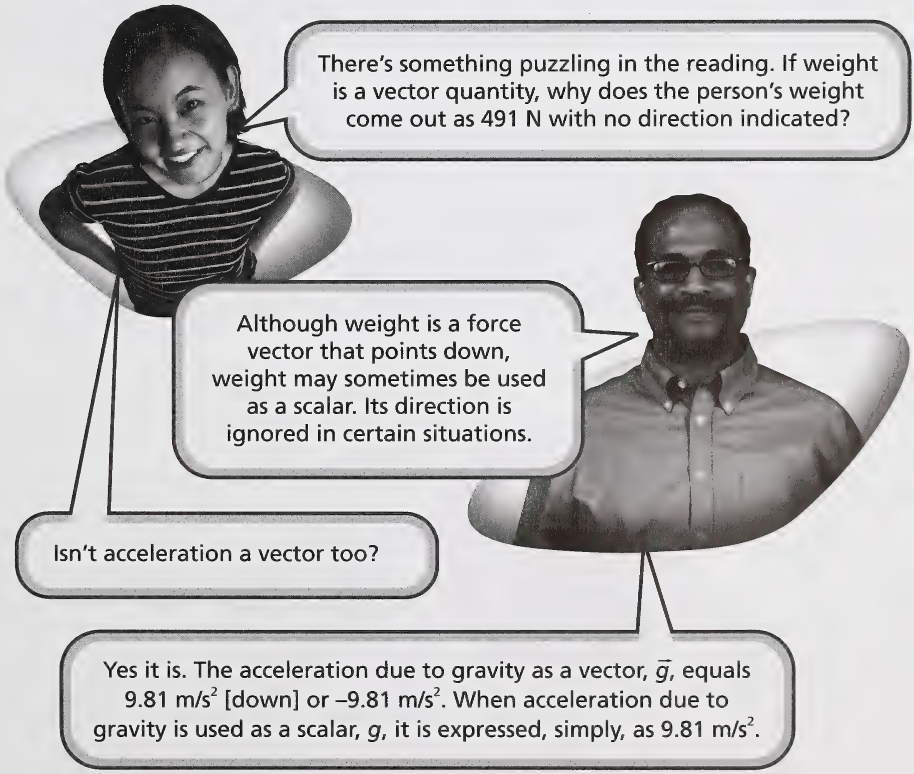
Weight-lifting is hard work. That's what makes weight-lifting good exercise. You have to apply a force to overcome the force of gravity on the weights. As you do work in lifting the weights, the weights gain gravitational potential energy. Gravitational potential energy is one of the various forms of **potential energy**.



Turn to page 173 of the textbook and read the introductory paragraphs of "Potential Energy." You will see how the potential energy of a midway car increases as it goes up.



Turn to pages 173 to 175 of the textbook and read "Gravitational Potential Energy." Read "*info*BIT" in the margin on page 173, and carefully work through Example Problems B2.1 and B2.2 on pages 174 and 175.



When using formulas to find gravitational potential energy, you may drop the vector notation in your calculations and simply use magnitudes for weight and acceleration due to gravity.

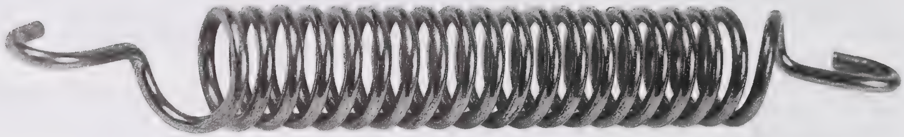
1. In the formula $E_{p(grav)} = mgh$, the variable(s) ____________ correspond(s) to force and the variable(s) ____________ correspond(s) to distance.

2. Answer questions 1, 2, and 3 of "Practice Problems" on pages 174 and 175 of the textbook.

Check your answers with those on pages 77 and 78.

elastic potential energy: energy stored in an object when its shape is stretched, twisted, or compressed

There's another type of potential energy stored in springs and elastics, called **elastic potential energy**. You can think of elastic potential energy as the energy an object has stored when it is stretched, twisted, or compressed.

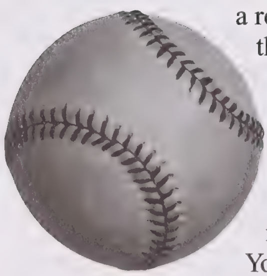


Refer to Figure B2.10 on page 175 of the textbook. The springs of the trampoline stretch as the kids land. These springs then retract as the kids bounce back up. Elastic potential energy is stored and released over and over.

Turn to page 175 of the textbook and read "Elastic Potential Energy."

3. Answer questions 4, 5, and 7 of "Check and Reflect" on page 178 of the textbook.

Check your answers with those on pages 78 and 79.



Imagine throwing a ball straight up into the air. Is there a relationship between the amount of work you do in throwing the ball and the gravitational potential energy of the ball at its maximum height?

To find out, you would have to measure the height the ball reaches and the energy you provide. Neither is easy to measure. However, you could investigate the relationship on a smaller scale—as in the next activity. You will see the relationship between the energy provided and gravitational potential energy more clearly.

Inquiry Lab

Catapults

Read the entire activity on pages 176 and 177 of the textbook.

4. Write a hypothesis for this activity.

Check Check your answer with the one on page 79.

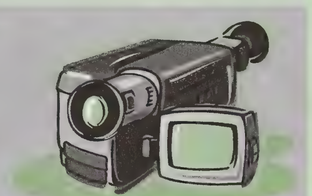
If you have access to the materials and equipment listed and a person to help you, do **Part A**. If you do not have access to the materials and equipment or a person to help you, do **Part B**.

Part A

Follow the steps outlined in the procedure.

Wear goggles to protect your eyes from the catapult. Make sure everybody is facing away from the catapult when firing, and never aim the catapult at others.

Note: If you have a digital camera or camcorder, you could have a helper take a movie of the catapulted objects in motion with the metre-stick in the background. Then you can see the maximum height the cork reaches by scanning back to the appropriate video frame.



5. Complete the table given at the bottom of page 176. **Note:** For calculation purposes, enter the mass of the cork in kilograms, not in grams.

6. Answer the following on page 177 of the textbook.

   a. questions 1 to 4 of "Analysis and Interpreting"
   b. question 5 of "Forming Conclusions"

Check Check your answers with those on pages 79 and 80.

Part B

Insert the Science 10 Multimedia CD into your computer and open the spreadsheet "Catapults." You will use this spreadsheet to answer the questions that follow.

7. Read through the table in the spreadsheet carefully and insert the missing information.

8. Answer the following on page 177 of the textbook.

   a. questions 1 to 4 of "Analyzing and Interpreting"
   b. question 5 of "Forming Conclusions"

Check Check your answers with those on page 80.

In the preceding Inquiry Lab, not all the elastic potential energy ended up as gravitational potential energy of the cork. There was some energy loss due to friction and air resistance. Yet, the activity demonstrated important characteristics of energy.

Turn to pages 177 and 178 of the textbook and read "Elastic and Gravitational Potential Energy and Catapults" and "Chemical Potential Energy."

9. Answer question 8 of "Check and Reflect" on page 178 of the textbook.

10. Pemican is a concentrated food traditionally used by First Nations peoples. Pemican is made of lean buffalo meat that is dried and pounded fine, bone marrow grease, and dried berries. Pemican is high in calories and can be stored for several years. What important type of potential energy does pemican have?

Check Check your answers with those on pages 80 and 81.

Looking Back

You have now completed the concepts for this lesson. You studied three forms of potential energy: gravitational, elastic, and chemical.

11. Answer question 2 of "Check and Reflect" on page 178 of the textbook.

Check Check your answers with those on page 81.

Go to ... Go to pages 3 and 4 of Assignment Booklet 2B and answer questions 4 to 9.

Glossary

elastic potential energy: energy stored in an object when its shape is stretched, twisted, or compressed

potential energy: energy stored and held in readiness to do work

Suggested Answers

1. In the formula $E_{p(grav)} = mgh$, the variable(s) $\boldsymbol{m}$ **and** $\boldsymbol{g}$ correspond(s) to force and the variable(s) $\boldsymbol{h}$ correspond(s) to distance.

2. **Textbook questions 1, 2, and 3 of "Practice Problems," pp. 174 and 175**

   1. $$\begin{aligned} E_{p(grav)} &= mgh \\ &= (25.0\ \text{kg})(9.81\ \text{m/s}^2)(4.00\ \text{m}) \\ &= 981\ \text{J} \quad \leftarrow \text{3 significant digits} \end{aligned}$$

   The gravitational potential energy of the child is 981 J.

2. $E_{p(grav)} = mgh$

$$h = \frac{E_{p(grav)}}{mg}$$

$$= \frac{47.0 \text{ J}}{(0.800 \text{ kg})(9.81 \text{ m/s}^2)} \quad \leftarrow \text{Convert grams to kilograms.}$$

$$= 5.99 \text{ m} \quad \leftarrow \text{3 significant digits}$$

The bird's vertical height is 5.99 m.

3. $E_{p(grav)} = mgh$

$$m = \frac{E_{p(grav)}}{gh}$$

$$= \frac{1.47 \times 10^3 \text{ J}}{(9.81 \text{ m/s}^2)(3.00 \text{ m})}$$

$$= 49.9 \text{ kg} \quad \leftarrow \text{3 significant digits}$$

The mass of the sign is 49.9 kg.

3. **Textbook questions 4, 5, and 7 of "Check and Reflect," p. 178**

4. a. $W = Fd$

$$= (32.0 \text{ N})(3.00 \text{ m})$$

$$= 96.0 \text{ J}$$

The work done against gravity is 96.0 J.

b. $\Delta E_{p(grav)} = W$

$$= 96.0 \text{ J}$$

The stored gravitational potential energy is 96.0 J.

5. Since $\Delta E_{p(grav)} = W$, 155 J of work must have been done during the lifting.

$W = Fd$

$$F = \frac{W}{d}$$

$$= \frac{155 \text{ J}}{1.20 \text{ m}}$$

$$= 129 \text{ N}$$

Recall: $1 \text{ J} = 1 \text{ N} \cdot \text{m}$

The force exerted on the object is 129 N [upwards].

7. $$\begin{aligned} \Delta E &= W \\ &= Fd \\ &= (500\ \text{N})(0.750\ \text{m}) \\ &= 375\ \text{J} \end{aligned}$$

The elastic potential energy stored in the trampoline is 375 J.

4. Answers will vary. A sample hypothesis is given.

   As the elastic potential energy of the catapult increases, the gravitational potential energy of the band also increases.

5. Answers will vary. Sample data is given.

Trial	Force on the Spring Scale $F_{(max)}$ (N)	Initial Distance of Spring Scale d_1 (m)	Final Distance of Spring Scale d_2 (m)	Distance the Spring Scale Moves d (m)	Elastic Potential Energy of the Elastic (work done on the elastic) $E_{p(elas)} = F_{(ave)}d$ (J)	Mass of Cork m (kg)	Initial Height of Cork h_1 (m)	Final Height of Cork h_2 (m)	Height the Cork Rises h (m)	Gravitational Potential Energy of Cork $E_{p(grav)} = mgh$ (J)
1	0.50	0.210	0.201	0.009	0.002	0.002	0.509	0.570	0.061	0.001
2	1.00	0.210	0.192	0.018	0.009	0.002	0.509	0.760	0.251	0.005
3	1.50	0.210	0.185	0.025	0.019	0.002	0.509	1.030	0.521	0.010
4	1.75	0.210	0.180	0.030	0.026	0.002	0.509	1.240	0.731	0.014
5	2.00	0.210	0.175	0.035	0.035	0.002	0.509	1.490	0.981	0.019

Remember: $F_{(ave)} = F_{(max)} \div 2$

6. a. **Textbook questions 1 to 4 of "Analyzing and Interpreting," p. 177**

   1. The manipulated variable is the elastic potential energy of the rubber band or the distance the rubber band is stretched.

   2. The responding variable is (maximum) gravitational potential energy or the height of the projectile.

   3. Theoretically, the elastic potential energy and the gravitational potential energy should be equal. Based on the experimental data, the gravitational potential energy is about half the elastic potential energy.

   4. Energy loss could be due to friction between the cork and the tube and due to air resistance.

b. **Textbook question 5 of "Forming Conclusions," p. 177**

5. Answers will vary depending on the hypothesis you made. A sample answer is given.

   The data supports the hypothesis that gravitational potential energy increases as elastic potential energy increases. The supporting data is evident in the Elastic Potential Energy of the Elastic (J) and the Gravitational Potential Energy of Cork (J) columns. The corresponding values in these columns increase together.

   Note: You may have started with a hypothesis that was not supported by the data. For example, your hypothesis may have been that the elastic potential energy is equal to the gravitational potential energy. If this was the case, you would not have data to back up your hypothesis. Corresponding values in the Elastic Potential Energy of the Elastic (J) and the Gravitational Potential Energy of Cork (J) columns are not equal.

   Sometimes a reasonable hypothesis is only weakly supported by the data. For example, you may have hypothesized that most of the elastic potential energy is converted into gravitational potential energy. By comparing the ratio of the corresponding values in the Elastic Potential Energy of the Elastic (J) and the Gravitational Potential Energy of Cork (J) columns, you will find that the gravitational potential energy is a little over half the elastic potential energy, somewhat supporting this hypothesis.

   When reflecting on how well a hypothesis is supported, you may discover other relations between the manipulated variable and the responding variable. Also, you may find that you have to discard the hypothesis or have to perform the experiment again.

7. Refer to the answer to question 5.

8. Refer to the answer to question 6.

9. **Textbook question 8 of "Check and Reflect," p. 178**

8. $$\begin{aligned} W &= \Delta E \\ &= 320\ \text{J} \end{aligned}$$

   $$\begin{aligned} W &= Fd \\ F &= \frac{W}{d} \\ &= \frac{320\ \text{J}}{0.100\ \text{m}} \\ &= 3.20 \times 10^3\ \text{N} \end{aligned}$$

   Note: This force is actually the average force.

   The average force used to stretch the elastic is 3.20×10^3 N.

10. Pemican has chemical potential energy.

11. **Textbook question 2 of "Check and Reflect," p. 178**

2. a. The compressed ball has elastic potential energy.

   b. At the 20th floor, the elevator has gravitational potential energy.

   c. The bent fibreglass bow has elastic potential energy.

   d. At the top of its flight, the arrow has gravitational potential energy. **Note:** Just after being released from the bow, the arrow has kinetic energy. As the arrow rises, its kinetic energy decreases and its gravitational potential energy increases.

   e. Before combustion, the gas has chemical potential energy.

Note: In each of these question parts, the object has chemical potential energy by virtue of its makeup. For example, the arrow may be made of wood, a combustible material. But having chemical potential energy is not relevant for the given situation.

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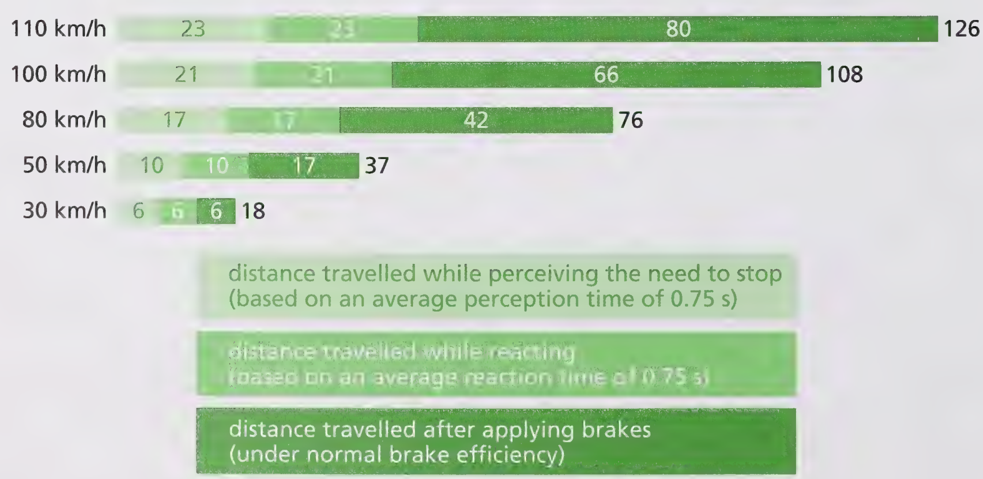
Lesson 3

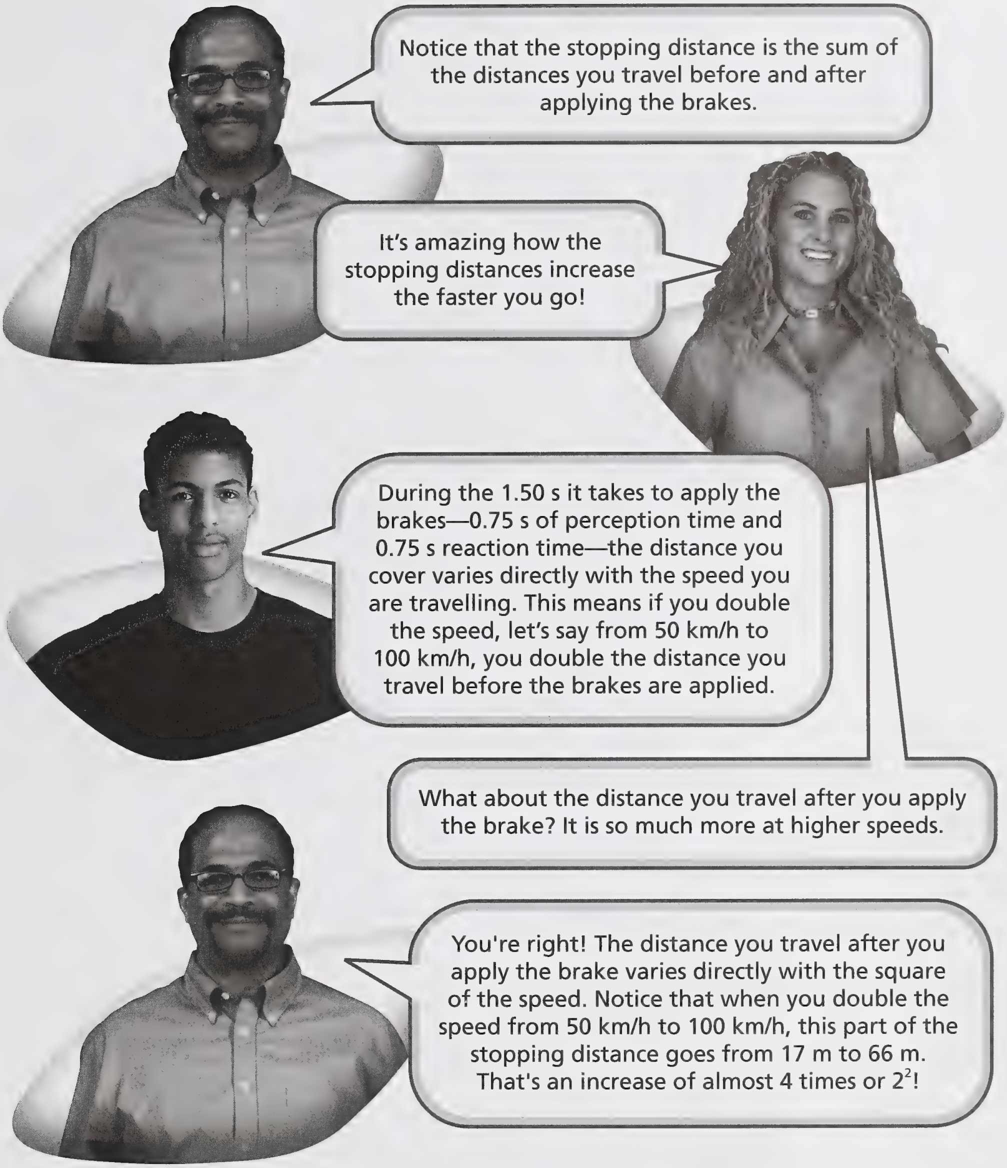
Kinetic Energy and Motion

Have you studied the Driver's Handbook recently? If so, you would have seen a graph like this, showing stopping distances for various speeds.

Stopping Distances Under Normal Road Conditions
(All distances are in metres.)



Information from the Basic Driver's Handbook provided by Alberta Infrastructure and Transportation. This handbook can be downloaded at **http://www.trans.gov.ab.ca/DriversInfo/Handbooks.asp**.



The relationship between the distance travelled after applying the brakes and speed is similar to another relation—the relation between the kinetic energy of an object and its speed.

Turn to page 179 of the textbook and read "*info*BIT." The information indicates that the kinetic energy of a snowball varies directly with the square of its speed and varies directly with its mass.

Now, read "Kinetic Energy and Motion" on pages 179 and 181. Work through the Example Problems B2.3, B2.4, and B2.5 carefully.

1. Answer questions 4 and 5 of "Practice Problems" on page 179 of the textbook.

2. Answer question 6 of "Practice Problems" on page 181 of the textbook.

Check Check your answers with those on pages 86 and 87.

Did You Know?

On January 29, 2005, the largest snowball fight ever recorded occurred in Wauconda, Illinois (a suburb of Chicago). The snowball fight consisted of a whopping 3027 participants! This beat the previous record of 2473 snowballers set in a small town in Switzerland in 2003.

Inquiry Lab

Kinetic Energy and Motion

Read the entire activity on pages 180 and 181 of the textbook.

If you have access to a supervised laboratory, do **Part A**. If you do not have access to a supervised laboratory, do **Part B**.

Part A

Follow the steps outlined in the procedure to complete this activity.

3. Copy and complete the table given at the bottom of page 180 by following steps 1 to 3 of "Analyzing and Interpreting" on page 181.

4. Answer question 4 of "Analyzing and Interpreting" on page 181 of the textbook.

Check Check your answers with those on pages 87 and 88.

Part B

Insert the Science 10 Multimedia CD into your computer, and view the segment "Kinetic Energy and Motion." Use the information from this segment to answer the following questions.

5. Copy and complete the table given at the bottom of page 180 of the textbook.

6. Answer question 4 of "Analyzing and Interpreting" on page 181 of the textbook.

Check Check your answers with those on page 88.

Looking Back

You have now covered the concepts for this lesson. You defined kinetic energy as the energy due to the motion of an object and determined the kinetic energy of moving objects.

7. Answer questions 3 and 8 of "Check and Reflect," on page 182 of the textbook.

I used a spreadsheet program to help me answer question 8. I recommend you use one too.

Check Check your answers with those on page 88.

Go to ... Go to pages 5 to 7 of Assignment Booklet 2B and answer questions 10 to 15.

Suggested Answers

1. **Textbook questions 4 and 5 of "Practice Problems," p. 179**

   4. $$\begin{aligned} E_k &= \frac{1}{2}mv^2 \\ &= \frac{1}{2}(9.11\times10^{-31}\ \text{kg})(2.00\times10^5\ \text{m/s})^2 \\ &= 1.82\times10^{-20}\ \text{J} \end{aligned}$$

   The kinetic energy of the electron is 1.82×10^{-20} J.

5. $E_k = \frac{1}{2}mv^2$

$$2E_k = mv^2$$

$$m = \frac{2E_k}{v^2}$$

$$= \frac{2(18\ \text{J})}{(2.2\ \text{m/s})^2}$$

$$= 7.4\ \text{kg}$$

$$\frac{\text{J}}{(\text{m/s})^2} = \frac{\text{kg}\cdot\cancel{\text{m}^2/\text{s}^2}}{\cancel{\text{m}^2/\text{s}^2}} = \text{kg}$$

The mass of the toy is 7.4 kg.

2. **Textbook question 6 of "Practice Problems," p. 181**

6. $E_k = \frac{1}{2}mv^2$

$$2E_k = mv^2$$

$$v^2 = \frac{2E_k}{m}$$

$$v = \sqrt{\frac{2E_k}{m}}$$

$$= \sqrt{\frac{2(304\ \text{J})}{0.300\ \text{kg}}}$$

$$= 45.0\ \text{m/s}$$

$$\sqrt{\frac{\text{J}}{\text{kg}}} = \sqrt{\frac{\text{kg}\cdot\text{m}^2/\text{s}^2}{\text{kg}}} = \sqrt{\text{m}^2/\text{s}^2} = \text{m/s}$$

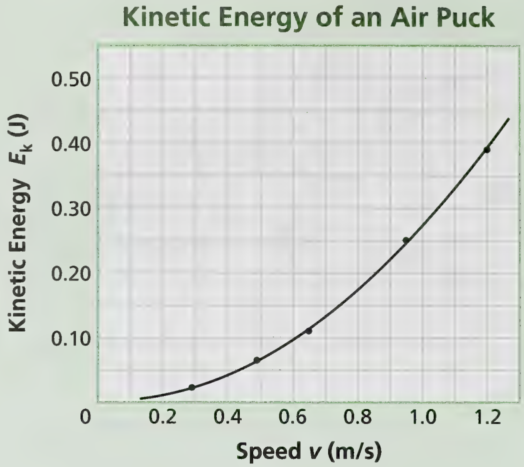
The speed of the baseball is 45.0 m/s.

3. Answers will vary. Sample data is given.

Trial	Mass of the Air Puck m (kg)	Time Interval of the Generated Sparks Δt (s)	Average Distance Travelled During Each Time Interval Δd (m)	Average Speed of the Air Puck v (m/s)	Kinetic Energy of the Air Puck E_k (J)
1	0.543	0.10	0.029	0.29	0.023
2	0.543	0.10	0.049	0.49	0.065
3	0.543	0.10	0.065	0.65	0.11
4	0.543	0.10	0.095	0.95	0.25
5	0.543	0.10	0.118	1.2	0.39

4. **Textbook question 4 of "Analyzing and Interpreting," p. 181**

   4. Answers will vary. A sample graph of the puck's kinetic energy as function of speed is given.



5. Refer to the answer to question 3.

6. Refer to the answer to question 4.

7. **Textbook questions 3 and 8 of "Check and Reflect," p. 182**

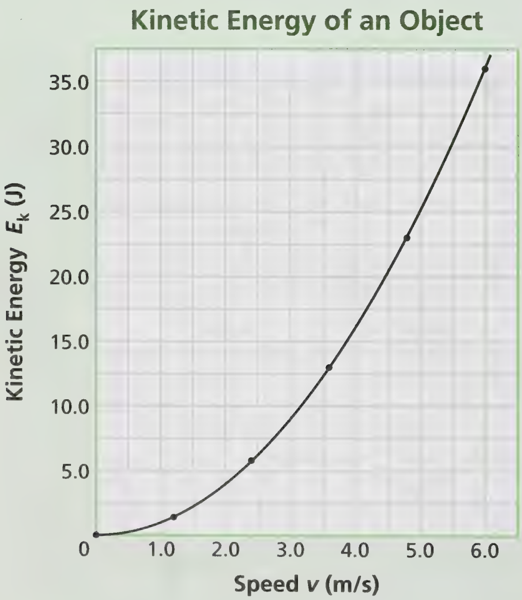
   3. $1\ \text{J} = 1\ \text{N}\bullet\text{m}$

   $$= 1\ (\text{kg}\bullet\text{m/s}^2)\bullet\text{m}$$

   $$= 1\ \text{kg}\bullet\text{m}^2/\text{s}^2$$

   Therefore, 1 J is equal to 1 $\text{kg}\bullet\text{m}^2/\text{s}^2$.

   8. a.



   b. The graph shows that kinetic energy varies directly with the square of the speed.

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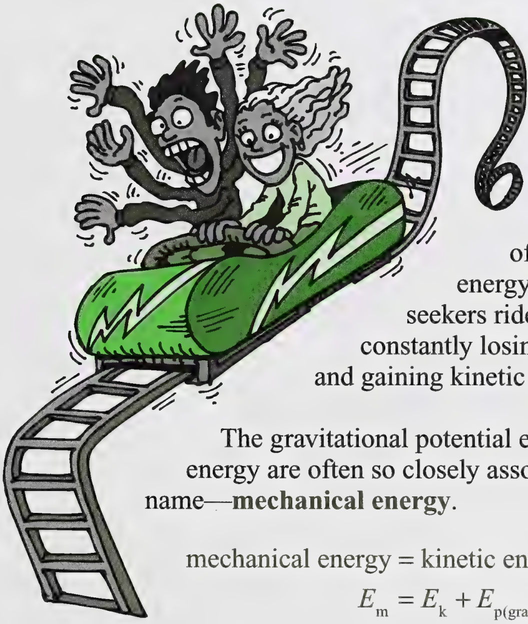
Lesson 4

Mechanical Energy



A roller coaster is a great example of the conversion of potential energy into kinetic energy. As the thrill seekers ride the roller coaster, they are constantly losing gravitational potential energy and gaining kinetic energy and vice versa.

The gravitational potential energy of an object and its kinetic energy are often so closely associated that their sum has a special name—**mechanical energy**.

mechanical energy: energy due to the motion and position of an object

mechanical energy = kinetic energy + gravitational potential energy

$$E_{m} = E_{k} + E_{p(grav)}$$

Turn to page 183 of the textbook and read the introductory paragraphs of "Mechanical Energy." Work through the Example Problem B2.6 carefully.

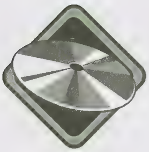
1. Answer question 10 of "Practice Problems" on page 183 of the textbook.

Check Check your answer with the one on page 94.

Many people have dropped things accidentally. Some objects drop faster than others. When a plate is dropped, it drops quickly. When a piece of paper is dropped, it falls slowly.

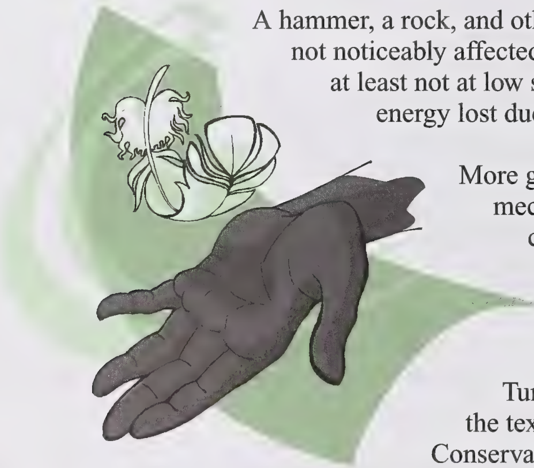
The way objects fall has been of particular interest to people investigating motion. Do you remember studying Galileo in previous science courses? He not only studied celestial objects, he investigated the behaviour of terrestrial bodies in motion. Galileo hypothesized that all objects fall with the same speed in the absence of air. On the Moon, where there is no atmosphere, objects released from equal heights would hit the Moon's surface at the same time.

In 1971, astronauts David Scott and Jim Irwin reached the Moon during the Apollo 15 mission. There they tested Galileo's lunar prediction for the first time.



Insert the Science 10 Multimedia CD into your computer. View the segment "NASA Lunar Feather Drop." Watch as Galileo's experiment is performed for the first time in a lunar environment.

Of course, the feather and hammer don't fall the same way on Earth. Air resistance slows down both objects. But, air resistance is less significant on the hammer than on the feather. That's why the hammer falls faster.



A hammer, a rock, and other "heavy" (or dense) objects are not noticeably affected by air resistance as they move—at least not at low speeds. In fact, for such objects, energy lost due to air resistance can be ignored.

More generally, you can think of mechanical energy as being conserved whenever you can ignore outside forces—such as friction and air resistance—that could affect motion.

Turn to pages 184 and 185 of the textbook and read "Law of Conservation of Energy." Work through Example Problems B2.7 and B2.8 closely.

Why objects exhibit changes in motion has puzzled philosophers and scientists for centuries. Earlier in this section, you explained changes in motion in terms of applied forces. The previous textbook reading showed how to use mechanical energy to explain the increase in speed of a falling object. With the concept of mechanical energy, you now have another way to explain changes in motion:

> A mechanical energy transfer leading to a change in an object's kinetic energy changes the speed of an object.

2. Answer questions 11, 12, and 14 of "Practice Problems" on pages 184 and 185 of the textbook.

Check Check your answers with those on pages 94 to 96.

You can apply the law of conservation of mechanical energy to solve question 13 of "Practice Problems" on page 185 of the textbook. But does the law of conservation of mechanical energy accurately describe real mechanical systems? That's the question for the next activity.

Inquiry Lab

Mechanical Energy and the Pendulum

Read the entire activity on pages 186 and 187 of the textbook.

For this lab, I'm going to use a spreadsheet program to help me analyze the data.

Review steps 1 to 8 of the procedure, and study Figure B2.14 closely.

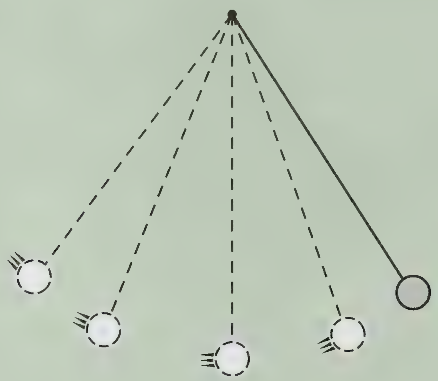
3. Using the information in Figure B2.14, calculate the potential energy of the pendulum before it is released if the hanging mass is 1.00 kg.

Check Check your answer with the one on page 96.

If you have access to a supervised laboratory and a motion sensor (with a computer interface), do **Part A**. If you don't have access to a supervised laboratory and a motion sensor, do **Part B**.

Part A

Follow the steps outlined in steps 1 to 12 of the procedure, and record your data in a table similar to the one given in the upper-right corner of page 187 of the textbook.



4. Answer the following on page 187 of the textbook.

   a. questions 3, 4, 5, 7, 8, 9, and 10 of "Analyzing and Interpreting"
   b. question 19 of "Forming Conclusions"

Check Check your answers with those on page 96.

Part B

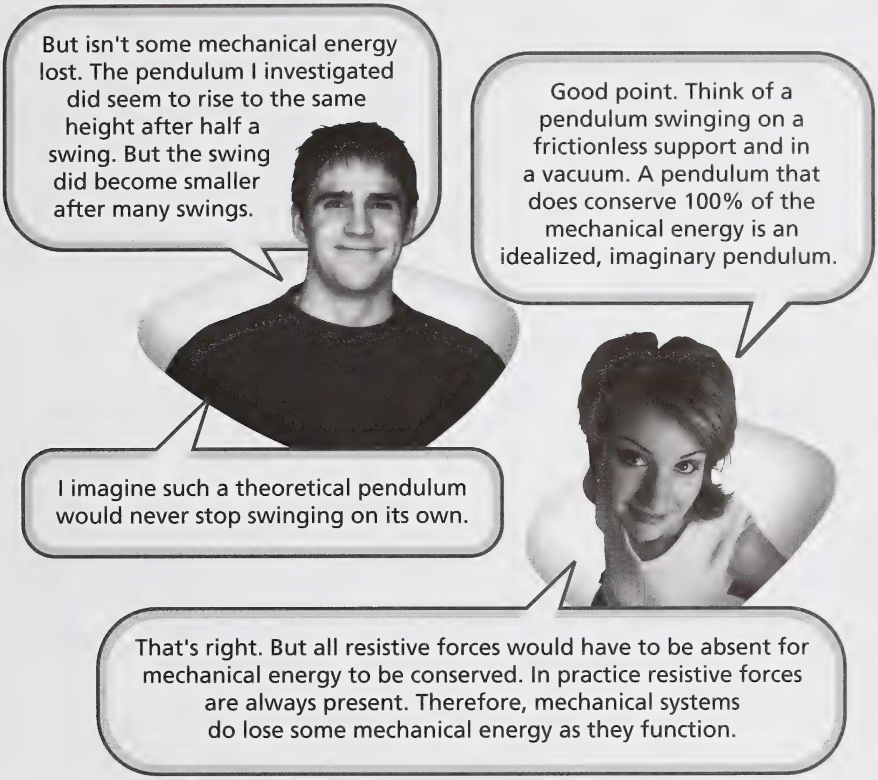
Use the sample data given in Method 2 of the procedure on page 187 of the textbook to answer the following. This data is based on the information given in Figure B2.14 and a hanging mass of 1.00 kg.

5. Answer the following on page 187 of the textbook.

   a. questions 11, 12, 13, 15, 16, 17, and 18 of "Analyzing and Interpreting"
   b. question 19 of "Forming Conclusions"

Check Check your answers with those on pages 97 and 98.

Turn to page 188 of the textbook and read “Conversion and Conservation of Energy in a Pendulum.” It discusses the conversion of energy during the swing of a pendulum.



Looking Back

You have now completed all the concepts for this lesson. You investigated the conversion of gravitational potential energy into kinetic energy and vice versa. You then used these conversions to test the concept of energy conservation.

6. Answer questions 1, 2, 5, 8, and 9 of “Check and Reflect” on pages 188 and 189 of the textbook.

Check Check your answers with those on pages 98 to 101.

Go to ... Go to pages 7 to 9 of Assignment Booklet 2B and answer questions 16 to 22.

Glossary

mechanical energy: energy due to the motion and position of an object

The amount of mechanical energy of an object is equal to the sum of the kinetic energy and gravitational potential energy of the object.

Mechanical energy is also used to refer to the energy of a moving machine part. For example, the turning shaft of an electric motor has mechanical energy due to the twisting force that gives it turning motion.

Suggested Answers

1. **Textbook question 10 of "Practice Problems," p. 183**

10. $$\begin{aligned} E_m &= E_k + E_{p(grav)} \\ E_k &= E_m - E_{p(grav)} \\ &= E_m - mgh \\ &= 1.88 \times 10^3 \text{ J} - (2.00 \text{ kg})(9.81 \text{ m/s}^2)(50.0 \text{ m}) \\ &= 1.88 \times 10^3 \text{ J} - 981 \text{ J} \\ &= 899 \text{ J} \end{aligned}$$

Note: Notice that the amount of mechanical energy that exceeds the gravitational potential energy of the hammer at 50 m must be kinetic energy of the hammer at that point.

The kinetic energy of the hammer 50 m above the ground is 899 J.

2. **Textbook questions 11, 12, and 14 of "Practice Problems," pp. 184 and 185**

11. At the end of the drop, all of the balloon's potential energy has converted into kinetic energy.

$$\begin{aligned} E_k &= E_p \\ \frac{1}{2}mv^2 &= mgh \\ v^2 &= \frac{2\cancel{m}gh}{\cancel{m}} \quad \leftarrow \text{Solve for } v. \\ v &= \sqrt{2gh} \\ &= \sqrt{2(9.81 \text{ m/s}^2)(12.0 \text{ m})} \\ &= 15.3 \text{ m/s} \end{aligned}$$

Note how mass has no bearing on the balloon's velocity.

The speed of the balloon just before it hits the ground is 15.3 m/s.

Note: Instead of combining the formulas, you can do the calculations separately.

First, determine the balloon's kinetic energy just before it hits the ground.

$$\begin{aligned} E_{\mathrm{k}} &= E_{\mathrm{p}} \\ &= mgh \\ &= (10.0\ \mathrm{kg})(9.81\ \mathrm{m/s^2})(12.0\ \mathrm{m}) \\ &= 1177.2\ \mathrm{kg{\bullet}m^2/s^2} \end{aligned}$$

$\leftarrow$ Do not round. Carry the entire number through to the end.

Now, use the kinetic energy formula to calculate the speed of the balloon just before it hits the ground.

$$\begin{aligned} E_{\mathrm{k}} &= \frac{1}{2}mv^2 \\ v^2 &= \frac{2E_{\mathrm{k}}}{m} \\ v &= \sqrt{\frac{2E_{\mathrm{k}}}{m}} \\ &= \sqrt{\frac{2(1177.2\ \mathrm{kg{\bullet}m^2/s^2}}{10.0\ \mathrm{kg}}} \\ &= 15.3\ \mathrm{m/s} \end{aligned}$$

12. $$\begin{aligned} E_{\mathrm{p(top)}} &= E_{\mathrm{k}} \\ mgh &= \frac{1}{2}mv^2 \\ h &= \frac{\frac{1}{2}\cancel{m}v^2}{\cancel{m}g} \\ &= \frac{v^2}{2g} \\ &= \frac{(1.60\ \mathrm{m/s})^2}{(2)(9.81\ \mathrm{m/s^2})} \\ &= 0.130\ \mathrm{m} \end{aligned}$$

$\leftarrow$ Solve for h.

Note how mass has no bearing on the height the child rises.

The child will rise 0.130 m.

14. At the bottom of the arc, the gravitational potential energy is zero. This means that all the mechanical energy has been converted into kinetic energy at this point.

$$
\begin{aligned}
E_{\mathrm{m}} &= E_{\mathrm{k}} + E_{\mathrm{p(grav)}} \\
E_{\mathrm{k}} &= E_{\mathrm{m}} - E_{\mathrm{p(grav)}} \\
E_{\mathrm{k}} &= E_{\mathrm{m}} \qquad \leftarrow E_{\mathrm{p(grav)}} = 0 \\
\frac{1}{2}mv^2 &= E_{\mathrm{m}} \\
v &= \sqrt{\frac{2E_{\mathrm{m}}}{m}} \qquad \leftarrow \text{Solve for } v. \\
&= \sqrt{\frac{(2)(0.491\ \mathrm{J})}{(0.500\ \mathrm{kg})}} \\
&= 1.40\ \mathrm{m/s}
\end{aligned}
$$

The speed of the ball at the bottom of the arc is 1.40 m/s.

3. Determine the height of the hanging mass before it is released.

$$
\begin{aligned}
h &= 1.0000\ \mathrm{m} - 0.7071\ \mathrm{m} \\
&= 0.2929\ \mathrm{m}
\end{aligned}
$$

Now, calculate the maximum potential energy.

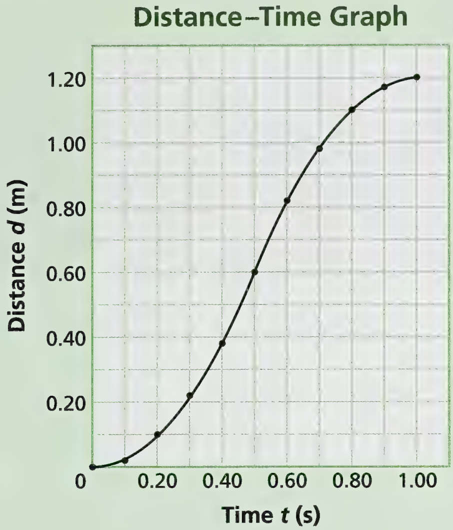
$$
\begin{aligned}
E_{\mathrm{p(grav)}} &= mgh \\
&= (1.00\ \mathrm{kg})(9.81\ \mathrm{m/s^2})(0.2929\ \mathrm{m}) \\
&= 2.87\ \mathrm{J}
\end{aligned}
$$

The maximum potential energy is 2.87 J.

4. Answers will vary. Sample answers are given in the answer to question 5. The answers to textbook questions 11 to 18 correspond to questions 3 to 10 respectively.

5. a. **Textbook questions 11, 12, 13, 15, 16, 17, and 18 of "Analyzing and Interpreting," p. 187**

11.



12. The graph curves upward to start, straightens out, then curves downward.

13. The shape indicates that the pendulum is moving with positive and negative accelerated motion; it is not moving in uniform motion.

15. The maximum speed reached by the pendulum is 2.40 m/s.

16. The pendulum reaches its maximum speed at the bottom of its swing (midpoint of the arc).

17. $$\begin{aligned} E_k &= \frac{1}{2}mv^2 \\ &= \frac{1}{2}(1.00\text{ kg})(2.40\text{ m/s})^2 \\ &= 2.88\text{ J} \end{aligned}$$

The maximum kinetic energy of the pendulum is 2.88 J.

18. The maximum kinetic energy of the pendulum is equal to its maximum potential energy.

b. **Textbook question 19 of "Forming Conclusions," p. 187**

19. Because the potential energy at the top of the arc is equal to the kinetic energy at the bottom of the arc, mechanical energy is conserved. The 0.01-J discrepancy between kinetic energy and potential energy is mainly due to inaccurate measurements, not friction.

> **Note:** If your data indicated that not all the mechanical energy was conserved, a measuring or calculation error may have occurred. Also, if you used an object with a very small mass as your hanging mass, resistive forces due to friction and air resistance, can interfere with the outcomes.

6. **Textbook questions 1, 2, 5, 8, and 9 of "Check and Reflect," pp. 188 and 189**

1. Mechanical energy is the sum of an object's kinetic energy and its gravitational potential energy. **Note:** The kinetic energy and gravitational potential energy of the object must be measured at the same time to correctly determine its mechanical energy.

2. a. At the moment the ball leaves the kicker's foot, the football has only kinetic energy.

   b. Halfway up to its highest point, the football has both kinetic energy and gravitational potential energy.

   c. At its highest point, the football mainly has gravitational potential energy. There is some kinetic energy due to its horizontal motion.

   d. If the ball had only vertical motion, the part of the motion where gravitational potential energy and kinetic energy would be equal is halfway up from its maximum height. Because of the ball's horizontal motion, the part of the motion where gravitational potential energy and kinetic energy would be equal is somewhat more than halfway up.

   e. The kinetic energy is least at the top of the trajectory.

   f. The gravitational potential energy is least at the beginning and end of the football's path, where the football is at its lowest point vertically.

   g. Assuming there is no loss of mechanical energy due to air resistance, the mechanical energy of the football is constant throughout its trajectory. Therefore, there is no point where the mechanical energy is greatest.

5. a.
$$\begin{aligned} W &= Fd \\ &= (40.0\text{ N})(0.100\text{ m}) \\ &= 4.00\text{ J} \end{aligned}$$

   The work done in compressing the spring is 4.00 J.

b. The work is stored in the spring as elastic potential energy.

c. Most of the energy stored in the spring converts into kinetic energy of the ball.

> **Note:** The end of the spring moves along with the ball during the spring's decompression. So, some of the spring's elastic potential energy is converted into kinetic energy of the end of the spring.

d. Assuming that all the elastic potential energy of the spring converts into kinetic energy of the ball, the ball will have 4.00 J of energy the moment it leaves the spring.

e.
$$
\begin{aligned}
E_k &= E_{p(elas)} \\
\frac{1}{2}mv^2 &= E_{p(elas)} \\
v^2 &= \frac{2E_k}{m} \\
v &= \sqrt{\frac{2E_{p(elas)}}{m}} \\
&= \sqrt{\frac{2(4.00\ \text{J})}{(1.00 \times 10^{-2}\ \text{kg}}} \\
&= 28.3\ \text{m/s}
\end{aligned}
$$

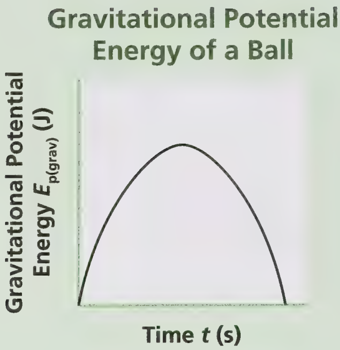
The speed of the ball when it leaves the spring will be 28.3 m/s.

f. The ball will gain 4.00 J of gravitational potential energy when it rises to its maximum height.

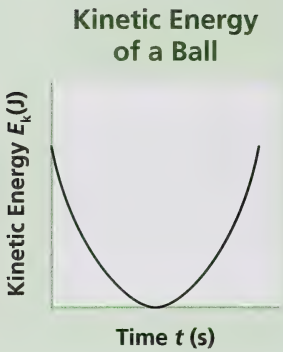
g.
$$
\begin{aligned}
E_{p(grav)} &= mgh \\
h &= \frac{E_{p(grav)}}{mg} \\
&= \frac{4.00\ \text{J}}{(1.00 \times 10^{-2}\ \text{kg})(9.81\ \text{m/s}^2)} \\
&= 40.8\ \text{m}
\end{aligned}
$$

The ball will reach a maximum height of 40.8 m.

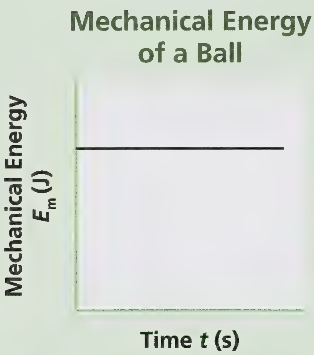
8. a.



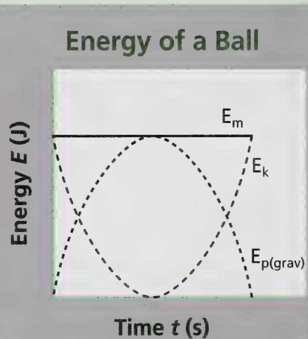
b.



c.



Note: If you put all three of these graphs on the same axes, it would look like the graph on the right. Note how the graphs of gravitational potential energy and kinetic energy are mirror images of each other. Also, note how the graph of mechanical energy is a line at the maximums of the other two graphs.



9. Assume that there is no energy "loss" due to friction and air resistance.

a. Because the ball is raised to a point where the string is horizontal, the ball has risen by 1.50 m. Therefore, $h = 1.50$ m.

$$\begin{aligned} E_{p(grav)} &= mgh \\ &= (2.00\ \text{kg})(9.81\ \text{m/s}^2)(1.50\ \text{m}) \\ &= 29.4\ \text{J} \end{aligned}$$

The amount of gravitational potential energy acquired is 29.4 J.

b. The maximum speed occurs when the ball reaches the bottom of its arc. At this point, the kinetic energy is equal to the gravitational potential energy before it was released. Therefore, $E_{k(bottom)} = 29.4$ J.

$$
\begin{aligned}
E_k &= \frac{1}{2}mv^2 \\
v^2 &= \frac{2E_k}{m} \\
v &= \sqrt{\frac{2E_k}{m}} \\
&= \sqrt{\frac{2(29.4\ \text{J})}{2.00\ \text{kg}}} \\
&= 5.42\ \text{m/s}
\end{aligned}
$$

The maximum speed of the ball is 5.42 m/s.

c. i. The ball will acquire its maximum gravitational potential energy at the end of the swing—the points where it is highest above ground.

ii. The ball will have its maximum kinetic energy at the bottom of its swing.

iii. The ball will have the same mechanical energy throughout its swing. So, there is no maximum or minimum mechanical energy throughout its swing.

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Lesson 5

Energy Conversions

Drying fish is an effective way to preserve food. It is important to preserve food for consumption for those days when the regular supply is unavailable.

Not only does food provide materials for tissue growth and repair, it also provides energy. Energy in food is released through energy conversions; the energy in food is converted into forms of energy that your muscles and your brain can use.

In this lesson you will consider many forms of energy and their conversions.

Turn to page 190 of the textbook and read the introductory paragraph of "Energy Conversions" and the information in "Evidence of Energy Conversions."

1. List four things that can result from energy conversions.

Check Check your answer with the one on page 105.

Many energy conversions occur in the human body. There are also many energy conversions in natural systems outside the human body.

Turn to pages 190 and 191 of the textbook and read "Energy Conversions in Natural Systems." You may want to review "Nuclear and Solar Energy" on page 167 of the textbook.

2. Answer questions 1, 2, and 3 of "Minds On . . . Identifying Energy Conversions in Nature" on page 191 of the textbook.

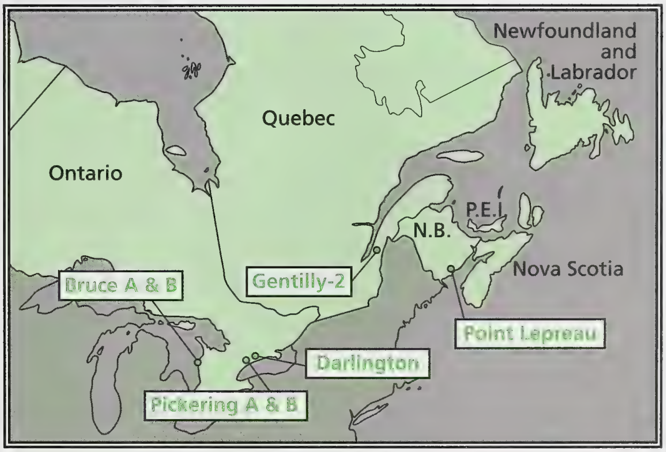
Check Check your answers with those on page 105.

Now, turn to page 192 of the textbook and read "Energy Conversions in Technological Systems."

3. Answer questions 2 and 3 of "Check and Reflect" on page 195 the textbook.

Check Check your answers with those on page 106.

Currently, there are seven nuclear power plants used for power generation in Canada. To find out more about these plants, turn to page 193 of the textbook and read "Nuclear Energy Conversions."



4. Answer question 5 of "Check and Reflect" on page 195 of the textbook.

Check Check your answer with the one on page 107.

Have you used a solar calculator to do your homework? You don't have to replace batteries in such a calculator because it can run off electricity from a small light-absorbing cell. Find out more about cells that produce electricity.

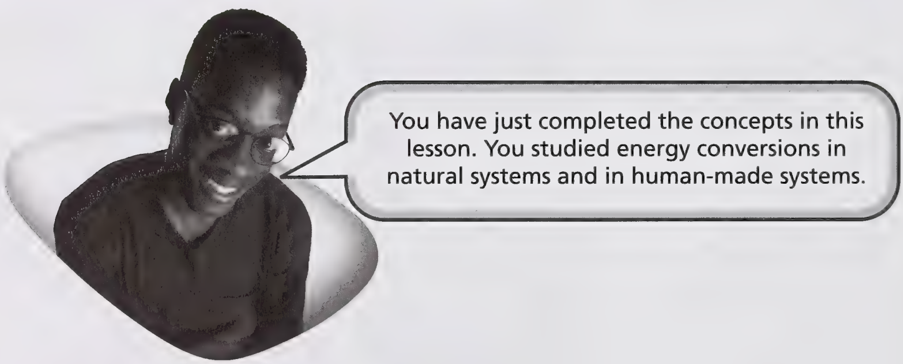
Turn to pages 193 to 195 of the textbook and read "Solar Energy Conversions" and "Fuel Cells."

5. Answer question 6 of "Check and Reflect" on page 195 of the textbook.

6. Answer question 29 of "Section Review" on page 197 of the textbook.

Check Check your answers with those on page 107.

Looking Back



7. Answer question 8 of "Check and Reflect" on page 195 of the textbook.

Check Check your answers with those on page 108.

Go to ... Go to pages 10 and 11 of Assignment Booklet 2B and answer questions 23 to 29.

Suggested Answers

1. The following can result from energy conversions:

   - An object starts moving or its motion changes in some way.
   - An object changes shape.
   - An object changes position.
   - An object changes in temperature.

2. **Textbook questions 1, 2, and 3 of "Minds On . . . Identifying Energy Conversions in Nature," p. 191**

   1. The energy conversions related to the production and use of fossil fuels are as follows:

      - Solar energy emitted from the Sun travels to Earth. This radiant energy is absorbed by green plants. Through photosynthesis, the energy is stored as chemical potential energy in the tissues of plants.

      - As plants die, they become buried deep within Earth. Heat and pressure acting over millions of years converted the plants into fossil fuels.

      - When fossil fuels are burned, the fuel's chemical potential energy is released as thermal energy.

   2. Not all the solar energy that strikes a plant is stored as chemical energy. Some of the incident light is reflected away from the plant's surface. Some of the incident light is converted into thermal energy rather than chemical potential energy.

   3. In photosynthesis, light energy, carbon dioxide, and water combine to produce carbohydrates and oxygen. In respiration, carbohydrates and oxygen combine to produce energy, carbon dioxide, and water. In combustion, combustible materials (not necessarily carbohydrates) combine with oxygen to produce carbon dioxide and water.

      Photosynthesis stores energy and produces oxygen. Respiration and combustion release stored energy and produce carbon dioxide. In this sense, photosynthesis is the reverse of respiration or combustion.

3. **Textbook questions 2 and 3 of "Check and Reflect," p. 195**

2. **Energy Conversions in a Coal-Burning Power Station**

chemical potential energy (of coal)

↓

thermal energy (due to combustion of coal)

↓

kinetic and elastic potential energy (of steam under pressure and in motion)

↓

kinetic energy (of rotating turbines)

↓

kinetic energy (of rotating coil in generator)

↓

electrical energy (in generator coil and out through transformer)

3. a. The energy conversion from the kinetic energy of the water into kinetic energy of the turbines produces the most waste thermal energy (heat). In this conversion there is a great deal of friction between the moving water and the blades of the rotating turbines.

> **Note:** The flowing water dissipates the thermal energy so there is little "heat buildup."

   b. The conversion of thermal energy of the hot steam into mechanical energy of the turbines produces most of the waste thermal energy (heat).

> **Note:** Cooling towers are used to dissipate the waste thermal energy (heat). There is also considerable thermal energy loss in the combustion chamber. This is where water is heated to produce steam.

4. **Textbook question 5 of "Check and Reflect," p. 195**

    5. Answers may vary. Various types of concept maps may be used. The amount of detail may vary. The following flowchart shows the main energy conversions.

       nuclear energy $\rightarrow$ thermal energy $\rightarrow$ mechanical energy $\rightarrow$ electrical energy

       The following depicts the energy changes in more detail.

       nuclear energy in fuel rods

       $\downarrow$

       thermal energy (due to nuclear fission)

       $\downarrow$

       kinetic and elastic potential energy (of steam under pressure and in motion)

       $\downarrow$

       kinetic energy (of rotating turbines)

       $\downarrow$

       kinetic energy (of rotating coil in generator)

       $\downarrow$

       electrical energy (in generator coil and out through transformer to power lines)

5. **Textbook question 6 of "Check and Reflect," p. 195**

    6. Solar cells are similar to batteries in that they both produce electricity. The positive and negative layers of the solar cell are similar to the positive and negative terminals of a battery.

6. **Textbook question 29 of "Section Review," p. 197**

    29. Solar cells are used for space stations because they produce electricity from the abundant solar radiant energy available in space. On Earth, there are other options for power generation. Electricity can be produced from coal-burning power stations, nuclear power plants, or from portable generators. Power lines from power generation plants distribute electricity. A space station is too isolated to depend on a terrestrial source of electricity.

7. **Textbook question 8 of "Check and Reflect," p. 195**

   8. Answers may vary. The energy chain may be indicated in paragraph form or in a concept map, such as a flowchart. Varying levels of detail may be shown in the energy chain. It is important that the energy chains clearly show that radiant energy from the Sun is the ultimate source of the final form of energy.

      a. **Energy chain leading to the warmth from the heating pad**

         nuclear energy (at the Sun) → radiant energy (to Earth) → chemical potential energy (through photosynthesis in plants) → chemical potential energy (in the form of fossil fuels) → thermal energy (when fossil fuels are burned in generating station) → thermal energy (of steam) → mechanical energy (of rotating turbines) → mechanical energy (of rotating generator) → electrical energy (from generator) → electrical energy (through home circuit and heating pad) → thermal energy (from heating pad)

      b. **Energy chain involving the idling lawn mower**

         nuclear energy (at the Sun) → radiant energy (to Earth) → chemical potential energy (through photosynthesis in plants) → chemical potential energy (in the form of fossil fuels) → chemical potential energy (in the form of gasoline) → thermal energy (when gasoline is burned in engine) → mechanical energy (of rotating engine and blade) plus waste thermal energy and sound energy → all waste thermal energy (since the mechanical energy is unused and also converted into thermal energy)

      c. **Energy chain to the "horse power"**

         nuclear energy (at the Sun) → radiant energy (to Earth) → chemical potential energy (through photosynthesis in plants) → chemical potential energy (in the form of food for horse) → chemical potential energy (in the form of blood glucose through digestion) → mechanical energy (of horse pulling the cart) plus waste thermal energy

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Conclusion

In this section you described historical discoveries leading to the concepts of energy and energy conversion. You surveyed a variety of forms of energy and used techniques to quantify various forms of energy. You then applied the law of conservation of energy to explain how mechanical devices work. You later identified energy conversions that occur naturally and in technological devices.

When using a bow and arrow, an archer does work in pulling the string. This causes the bow to flex and store elastic potential energy. When the archer releases the arrow, elastic potential energy of the bow is converted into kinetic energy of the arrow.

The operation of many technological devices involves the conversion of energy from one form into another form.

Section Three

Energy Transformations and Efficiency

A big part of Canada's heritage was the completion of the railway and the introduction of the steam locomotive. The steam locomotive opened the West to the rest of Canada for both passenger and transport services. Did your ancestors travel to Alberta, or anywhere else for that matter, by steam train? Railway companies have since replaced the majestic steam locomotives with the popular diesel engines. These days, you can still see the great steam engines at work at Fort Edmonton Park and Calgary Heritage Park.

The development of a practical steam engine in the eighteenth century started the Industrial Revolution. Factory looms and machinery in mills were made possible by the power from steam engines. However, the early steam engines were very inefficient; they wasted a lot of heat. In studying ways to improve the efficiency of the steam engine, much was learned about mechanical forces, motion, and heat.

In this section you will interpret laws that deal with forces, motion, and the transfer of thermal energy. You will also examine the development of engines and other machines during the Industrial Revolution. This development led to the understanding of energy and the limitations of devices that convert energy. Later, you will compare the efficiency of modern devices and consider the environmental impact of energy use.

Turn to page 198 of the textbook and read the introduction to Unit B 3.0. Pay particular attention to the key concepts and learning outcomes listed. They provide a brief overview of what you will cover in this section.

Lesson 1

Laws of Thermodynamics

The Alberta Legislature is where laws are made specifically for the province of Alberta. Scientific laws are quite different from those enacted in the legislature. Scientific laws are discovered, not made; enacted laws are rules that people must abide by. Scientific laws describe what actually happens in certain situations. These laws are based on numerous observations.

system: a set of interconnected parts

The laws of thermodynamics describe events involving heat and its conversion into mechanical and other forms of energy within a **system**.

Turn to page 199 of the textbook and read the introduction to "Laws of Thermodynamics" and the information provided in "Systems."

1. List the three types of systems.

Check Check your answer with the one on page 117.

You are already familiar with the law of conservation of energy. Earlier you used a pendulum to show the conservation of mechanical energy. The **first law of thermodynamics** covers not only mechanical energy, but also heat and all other forms of energy.

first law of thermo-dynamics: a law stating that the total energy, including thermal energy (heat), in a system and its surroundings remain constant

Turn to pages 199 and 200 of the textbook and read "The First Law of Thermodynamics and the Law of Conservation of Energy."

2. When the brakes of a moving car are applied, the car loses its kinetic energy. The brakes bring the car to a stop. Does the loss of the car's kinetic energy go against the first law of thermodynamics?

Check Check your answer with the one on page 117.

perpetual motion machine: a hypothetical machine in which all the input energy converts completely into mechanical energy; perfect machine

Imagine a **perpetual motion machine**. Once set in motion, a perpetual motion machine will remain in motion forever without having to add any additional energy. For example, look at the wheel in Figure B3.4 on page 202 of the textbook. As the spokes of the wheel move upward, the steel ball bearings roll toward the centre (the axle); as the spokes move downward, the steel ball bearings roll outward. The ball bearings rolling outward would then exert a greater leverage on the wheel than the ball bearing on the other side rolling inward. It is this greater leverage that would supposedly keep the wheel turning in spite of the little bit of friction at the axle.

Because of the leverage within the wheel, you might expect that this machine could create some mechanical energy; but the first law of thermodynamics—energy can neither be created nor destroyed—contradicts this expectation.

Does a bouncing ball resemble a perpetual motion machine? When dribbling a basketball, you keep the ball going by repeatedly pushing the ball toward the floor with your hand. What happens when balls bounce without your input of mechanical energy? You will examine this in the next investigation.

Inquiry Lab

Bouncing Balls

Read the entire activity on page 201 of the textbook.

3. Identify the manipulated, responding, and controlled variables.

Check Check your answer with the one on page 117.

If you have access to the materials and equipment listed and have a partner to help you, do **Part A**. If you do not have access to these resources, do **Part B**.

Part A

4. Review "The Hypothesis" on page 201 of the textbook.

   a. Which ball do you think will convert energy the best during a bounce?

   b. How would you determine which ball bounces most like a perfect machine?

Check Check your answers with those on page 117.

Follow the steps outlined in the procedure to test your predictions.

A camcorder may help you record the height that each ball bounces.

5. Show your results by completing the table given at the bottom of page 201 of the textbook.

6. Answer the following on page 201 of the textbook.

   a. questions 1 and 3 of "Analyzing and Interpreting"
   b. questions 4, 5, and 6 of "Forming Conclusions"

Check Check your answers with those on pages 117 and 118.

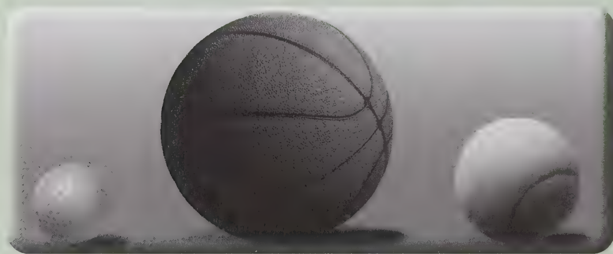
Part B

7. Review to "The Hypothesis" on page 201 of the textbook.

   a. Suppose a golf ball, a basketball, and a tennis ball are bounced on a concrete floor. Which of these balls do you think will convert energy the best during a bounce?

   b. How would you determine which ball bounces most like a perfect machine?

Check Check your answers with those on page 118.



8. Two students followed the steps of the procedure closely and recorded the following data. Complete the table.

Type of Ball	Mass of the Ball m (kg)	Starting Height h (m)	Starting Potential Energy $E_p = mgh$ (J)	Average Return Height h (m)	Ending Potential Energy $E_p = mgh$ (J)	Loss of Potential Energy ΔE_p (J)
golf ball	0.045	1.00		0.85		
basketball	0.595	1.00		0.73		
tennis ball	0.057	1.00		0.53		

9. Answer the following on page 201 of the textbook.

   a. questions 1 and 3 of "Analyzing and Interpreting"
   b. questions 4, 5, and 6 of "Forming Conclusions"

Check Check your answers with those on page 118.

For further discussion about the preceding activity, read "The Perfect Machine Cannot Be Achieved" on page 202 of the textbook.

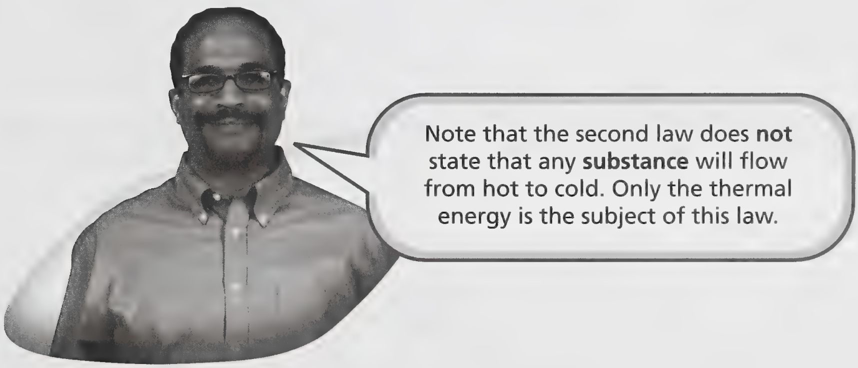
According to the first law of thermodynamics, a bouncing ball will never start bouncing higher and higher on its own. If the bounce did go to a higher level, energy—in the form of mechanical energy—would have been created. That violates the first law. On the other hand, the ball could keep bouncing like a perfect machine forever **if** there were no energy lost to the surroundings. This would not violate the first law, but it would violate another law—the **second law of thermodynamics**.

second law of thermo-dynamics: a law stating that heat always flows naturally from a hot object to a cold object and never naturally from a cold object to a hot object

Turn to pages 202 and 203 of the textbook and read "The Second Law of Thermodynamics."

There are several ways to express the second law:

- Thermal energy always flows naturally from a hot object to a cold object; it never flows naturally from a cold object to a hot object.
- No process can remove thermal energy from a source and convert it entirely into mechanical energy. Some of the thermal energy from the source will remain as thermal energy.
- No process can be 100% efficient. Some energy will always be lost as heat.
- Work is needed to make thermal energy move from cold to hot.



10. Answer questions 4 and 10 of "Check and Reflect" on page 205 of the textbook.

Check Check your answers with those on pages 118 and 119.

There's a way to gain more insight into the second law. Look at mechanical devices designed to convert heat into mechanical energy and the other way around.

Turn to pages 204 and 205 of the textbook and read "Heat Engines and Heat Pumps."

11. Answer question 5 of "Check and Reflect" on page 205 of the textbook.

Check Check your answer with the one on page 119.

Looking Back

You have now completed the concepts in this lesson. You studied laws describing the relationship between heat, work, and mechanical energy.

12. Answer questions 1, 6, 7, 11, and 12 of "Check and Reflect" on page 205 of the textbook.

Check Check your answers with those on pages 119 and 120.

Go to ... Go to pages 1 to 3 of Assignment Booklet 2C and answer questions 1 to 7.

Glossary

first law of thermodynamics: a law stating that the total energy, including thermal energy (heat), in a system and its surroundings remains constant

perpetual motion machine: a hypothetical machine in which all the input energy converts completely into mechanical energy; perfect machine

second law of thermodynamics: a law stating that heat always flows naturally from a hot object to a cold object and never naturally from a cold object to a hot object

system: a set of interconnected parts

Suggested Answers

1. The three types of systems are an open system, a closed system, and an isolated system.

2. The loss of the car's kinetic energy does not go against the first law of thermodynamics. The kinetic energy of the moving car is converted into thermal energy due to friction at the brake pads.

3. **manipulated variable:** type of ball

   responding variable: height of ball after bounce (or gravitational potential energy of ball after bounce)

   controlled variables: starting height of ball (or starting gravitational potential energy of ball) and type of floor surface

4. a. Answers will vary depending on the balls used. A sample answer is given based on using a golf ball, a basketball, and a tennis ball.

   A golf ball will likely convert energy the best and bounce the highest.

   b. The ball that bounces back closest to its starting height would be most like a perfect machine. A ball like this very efficiently converts kinetic energy into elastic potential energy and back again.

5. Results will vary. Sample data is given based on a golf ball, a basketball, and a tennis ball.

Type of Ball	Mass of the Ball m (kg)	Starting Height h (m)	Starting Potential Energy $E_p = mgh$ (J)	Average Return Height h (m)	Ending Potential Energy $E_p = mgh$ (J)	Loss of Potential Energy ΔE_p (J)
golf ball	0.045	1.00	0.44	0.85	0.38	0.06
basketball	0.595	1.00	5.84	0.73	4.26	1.58
tennis ball	0.057	1.00	0.56	0.53	0.30	0.26

6. a. **Textbook questions 1 and 3 of "Analyzing and Interpreting," p. 201**

   1. The energy conversions of the ball are follows:

      gravitational potential energy $\xrightarrow{\text{as ball falls}}$ kinetic energy $\xrightarrow{\text{as ball hits floor}}$ elastic potential energy $\xrightarrow{\text{as ball bounces back}}$ kinetic energy $\xrightarrow{\text{as ball rises after bounce}}$ gravitational potential energy

3. The lost energy is converted into thermal energy. Although there is less mechanical energy after the ball bounces, this does not contradict the first law of thermodynamics. The sum of the gravitational potential energy of the ball after the ball bounces to its maximum height and the thermal energy produced equals the original gravitational potential energy of the ball. So, energy is still conserved.

b. **Textbook questions 4, 5, and 6 of "Forming Conclusions," p. 201**

For questions 4 and 5, answers will vary. Sample answers are given based on the sample data given.

4. The golf ball best resembles a perfect machine. It bounced the highest.

5. The tennis ball least resembles a perfect machine. It bounced the lowest.

6. Answers will vary depending on your hypothesis. If you hypothesized that the golf ball would convert energy the best, then the results of the experiment agree with your hypothesis.

7. Refer to the answer to question 4.

8. Refer to the answer to question 5.

9. Refer to the answer to question 6.

10. **Textbook questions 4 and 10 of "Check and Reflect," p. 205**

4. a. The bouncing ball eventually comes to rest because energy is lost as heat, according to the second law of thermodynamics.

b. A metal spoon becomes hot when in hot water because heat flows from hot to cold. This is best explained by the second law of thermodynamics.

c. Energy cannot be created or destroyed. This is the first law of thermodynamics in a nutshell.

10. Answers will vary. This question is to stimulate thinking about the laws of thermodynamics from a common sense point of view. Answers may vary depending on how the given statements are interpreted. Sample answers are given.

a. You can't get something for nothing is part of what the first law of thermodynamics says about energy in general—you cannot create energy.

b. You can't even get close (to getting something for nothing) suggests that you lose a lot of whatever you start out with. The second law of thermodynamics describes this idea. One version of the second law of thermodynamics states that no process can be 100% efficient. Some energy will always be lost (as heat).

c. There are two possible answers.

- The energy to propel the rock into the air cannot be created. This would violate the first law of thermodynamics.

- A rock jumping into the air might be due to the conversion of the thermal energy of soil into mechanical energy. This is not going to happen, because the flow of thermal energy is naturally from hot to cold. Because the soil is cooler than the rock, the flow of energy would be from the rock to the soil, not the other way around.

11. **Textbook question 5 of "Check and Reflect," p. 205**

5. A heat engine converts thermal energy into mechanical energy. Examples include jet engines, automobile engines, and steam engines.

A heat pump uses mechanical energy to transfer thermal energy. Examples include refrigeration systems and air conditioners.

Note: Some air conditioners in reverse cycle can provide heat to a building when it's not too cold outside. In reverse cycle, air conditioners transfer thermal energy from the air outside the building to the interior of the building. Running an air conditioner in reverse cycle to heat a building consumes less electricity than using an electric heater with heating elements!

12. **Textbook questions 1, 6, 7, 11, and 12 of "Check and Reflect," p. 205**

1. Answers may vary. Sample responses are given.

- *Thermodynamics* is the study of the relationship between thermal energy, work, and mechanical energy.

- *Thermodynamics* is the study of the relationship between heat, work, and energy.

- *Thermodynamics* is the field of science that deals with force and motion involving heat.

6. A perpetual motion machine is an imaginary perfect machine that converts all of its input energy into mechanical energy.

7. Answers will vary. There are various versions of the second law of thermodynamics. Although the versions look different, they all come from the idea that thermal energy always flows naturally from a hot object to a cold object.

   - Thermal energy always flows naturally from a hot object to a cold object; it never flows naturally from a cold object to a hot object.

   - No process can remove thermal energy from a source and convert it entirely into mechanical energy. Some of the thermal energy from the source will remain as thermal energy.

   - No process can be 100% efficient. Some energy will always be lost as heat.

   - Work is needed to make thermal energy move from cold to hot.

11. Answers will vary according to the reasoning provided. The first law of thermodynamics will have to be used in the reasoning. A sample answer that refers to both laws is given.

    You cannot cool down a room by simply leaving the door of a refrigerator open. Think of the room as a closed system for a moment. All the refrigerator will do is transfer thermal energy within the room. This transfer does not in itself cool (or heat) the room. Energy cannot be destroyed according to the first law of thermodynamics. Without a loss of thermal energy, no cooling will take place.

    But the imagined room is not a closed system, even if it is well insulated. Electrical energy enters this room to keep the refrigerator going. With the refrigerator door open, the refrigerator takes even more electrical energy because it is constantly running. The second law of thermodynamics indicates that no device is 100% efficient. Therefore, the electrical energy converts into mechanical energy and some waste thermal energy. The mechanical energy then converts into additional thermal energy due to the total inefficiency of the open-door refrigerator. The net effect of leaving the refrigerator door open is that it makes the room even warmer.

12. A perpetual motion machine is a machine that supposedly operates without loss of energy. A specific task may not be associated with such a machine. A Rube Goldberg machine is designed to complete a specific task without regard to the amount of energy it wastes.

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Lesson 2

The Development of Engine Technology

Think about how motor vehicles today affect your life. Could you carry on with your current lifestyle without being able to drive anywhere or hop on a bus? Without motor vehicles, it makes it pretty tough to make it to dance lessons across the city or to play hockey in a town 50 km away. It was the invention of engine technology that has allowed the comforts and freedom motor vehicles provide.

What were the events leading to the development of engine technology? To find out, turn to pages 206 and 207 of the textbook and read the introduction to "The Development of Engine Technology."

1. Why did the scarcity of trees in England lead to a need for a powerful engine?

2. Figure B3.11 shows a reciprocating pump.

   a. Which one-way valve opens during the half cycle when the piston moves to the left?

   b. Explain why the top one-way valve opens and shuts every cycle.

Check Check your answers with those on page 130.

Most people enjoy a soft drink now and then. The technological development of the tin can makes having the soft drink so convenient. The history of the tin can illustrates the role of trial and error in technological development.

An early version of soft drink containers had a removable tab. With thousands of these cans in use, a great number of tabs became litter. This littering was recognized as an environmental problem, thus leading to the idea that the tab should stay attached after the can is opened. So, manufacturers developed a can with a "non-removable" tab.

It isn't just trial and error that guides technological development. Applying concepts from science is also important. Think back to the hydraulic lift from previous science courses. In designing a hydraulic lift, Pascal's law can be applied—the lift can be made to provide a specific mechanical advantage. Pascal's law can also be used to predict the strength needed for the wall enclosing the hydraulic lift. Using science concepts will likely reduce the time needed to get the device right.

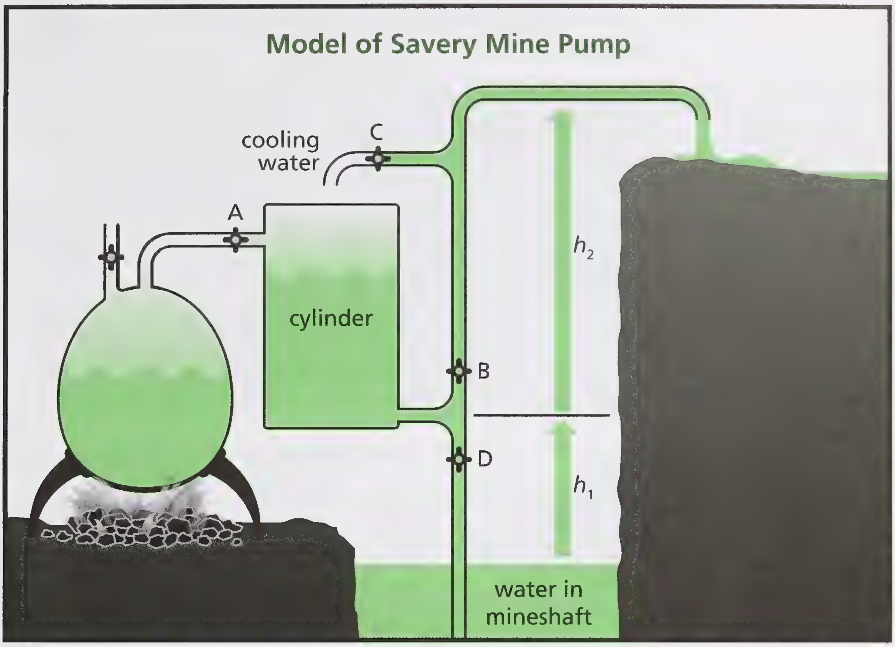
Having the appropriate technology at hand is also important. Imagine trying to build a tin can or hydraulic lift without having metal refineries supplying metals. Even a wheelbarrow would be hard to envision without the invention of the wheel. The development of the telescope depended on the development of glass. Technological development involves building on technology already in place—which you can think of as enabling technology.

The development of engine technology illustrates typical aspects of technological development.

Turn to pages 207 and 208 of the textbook and begin reading "Developing a Technology." For now, read the subsections "The Gunpowder Engine," "The Heat Engine," "The Savery Engine," and "The Newcomen Engine."

3. Denis Papin designed a steam-powered engine. Which enabling technology did Papin need in order to build his steam-powered engine?

Check Check your answer with the one on page 130.



The Savery pumps water out of a mine by alternately forcing water out of a cylinder and then drawing water into the cylinder. It uses the thermal energy from the flame under the boiler.

Water is forced out of the cylinder. Water is heated to produce steam under pressure. With valves A and B open and valves C and D closed, water is forced by steam pressure out of the cylinder to h_2 and out the spout.

Water is drawn into the cylinder. When the cylinder water level has dropped and the cylinder is full of steam, valves A and B are closed and valve D opened to restrict inflow only to the pipe going down the mine shaft. Valve C is opened to drop cold water on the cylinder. Steam condenses leaving a partial vacuum in the cylinder. The water in the mineshaft rises to a height of h_1.

4. What type of pressure forces water up the mineshaft pipe into the cylinder of the Savery pump?

5. Match each steam engine to the location where its fuel is burned.

Type of Steam Engine	Where Fuel Is Burned
a. Papin-designed steam engine	i. in a booster
b. Savery engine	ii. in the cylinder of the engine
c. Newcomen engine	iii. under a boiler
	iv. under the cylinder of the engine

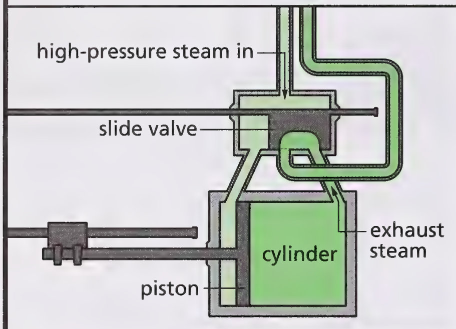
6. Why did the Newcomen engine need tremendous amounts of thermal energy to function?

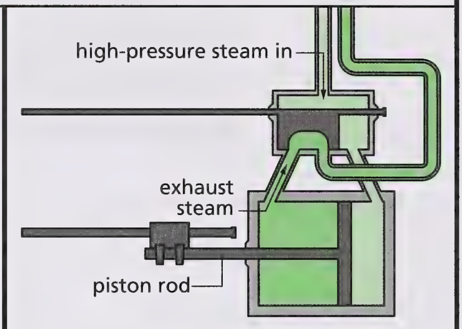
Check your answers with those on page 130.

In the Newcomen engine, steam applied pressure to only one side of a piston. The Watt engine was designed to apply steam pressure to both sides of a piston—one side and then the other.

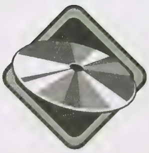
Turn to page 209 of the textbook and read "The Watt Engine." Then closely study the following diagrams to see how the piston of this engine is pushed in two directions by steam pressure.

Steam Engine





Slide valve directs high-pressure steam to the left side of the piston and allows cool, spent gas to exhaust. Piston moves to the right due to pressurized steam on the left side of the cylinder.	Slide valve directs high-pressure steam to the right side of the piston and allows cool, spent gas to exhaust. Piston moves to the left due to pressurized steam on the right side of the cylinder.



Insert the Science 10 Multimedia CD into your computer, and view the segment "Steam Engine Operation" for more information about the Watt engine.

7. What change made the Watt engine more efficient than the Newcomen engine?

8. What characteristic of the Watt engine made it unsuitable for automobiles?

Check your answers with those on page 130.

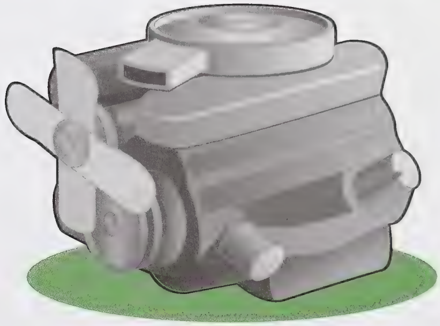
Going Further

Are you interested in finding out more about the history of the steam engine? You can start by visiting the following website:

http://technology.niagarac.on.ca/people/mcsele

Once there, click on "History of Technology" in the menu items on the left side of the page. Then click on the article "Early Steam Engine Technologies."

It was the invention of the internal combustion engine that made freeway traffic possible. If someone told you that car engines work like a gunpowder engine, would you believe him or her? Well, believe it! The earliest inventors of internal combustion engines based their ideas on Huygens's design of a century earlier—a design for a gunpowder engine.



Turn to pages 210 and 211 of the textbook and read "The Internal Combustion Engine." Closely study the animation of a piston in one cylinder of an engine given in Figure B3.17.

Going Further

To see an animation showing the engine parts in motion, visit

http://auto.howstuffworks.com/engine4.htm

You will see engine parts work in unison to extract energy from gasoline.

9. Answer questions 4, 5, 8, and 9 of "Check and Reflect" on page 214 of the textbook.

Check Check your answers with those on pages 130 and 131.

Beasts of burden have been important in agriculture and in transportation. This changed with the development of efficient motors and engines. Animal power was no longer an important source of energy in industrialized societies. In the next activity you will look into the contemporary use of motors and engines.

Turn to page 211 of the textbook and read "Minds On . . . Motors and Engines Today."

10. Complete the summary data table as described in Part A. Think of the term *engines* as referring to either motors or engines.

11. Answer questions 1, 2, and 3 of "Minds On . . . Motors and Engines Today."

12. Do Part B to determine the importance of motors and engines in Canadian society. If you are unable to find a partner, complete the task on your own. Then, based on your research, write a paragraph describing the importance of engines and motors to a modern industrialized society.

Check Check your answers with those on pages 131 and 132.

Many of the engines and motors in use today are complex machines. However, you can build a simple heat engine to demonstrate the conversion of thermal energy into a useful form of energy.

Before doing the next activity, you may want to review "Student Reference 3: The Problem-Solving Process" on pages 461 and 462 of the textbook. There are nine steps altogether in the problem-solving process. Note how each part outlined in the next activity corresponds to steps of the problem-solving process.

Problem-Solving Investigation

Using Steam to Power Boats

Read the entire activity on pages 212 and 213 of the textbook.

If you have access to a supervised laboratory, do **Part A**. If you do not have access to a supervised laboratory, do **Part B**.

Part A

Follow steps 1 to 8 of "Build a Prototype" on page 212. **Pay special attention to the safety precautions mentioned.** Then follow steps 9 to 16 of "Test and Evaluate" on page 213.

13. Complete a data table according to step 16 of "Test and Evaluate."

14. Continue with step 17 of "Test and Evaluate"; then answer questions 1 and 3 of " Communicate."

Check Check your answers with those on page 132.

Part B

A Science 10 student completed this activity and achieved the following results. Study these results closely, and use them to answer question 15.

Modification Made to the Steamboat	Trial #	Time Taken for the Steamboat to Travel 15 cm (s)
original design	1	N/A moved in a small circle
	2	N/A moved in a small circle
moved medicine dropper a bit off centre through the back of the boat	1	27 s moved fairly straight
	2	24 s moved fairly straight
with medicine dropper still a bit off centre, added a third candle to heat the test tube	1	21 s
	2	25 s

15. Answer questions 1 and 3 of "Communicate" on page 213 of the textbook.

Check Check your answers with those on page 132.

The invention of engines and motors has changed life from pre-industrial times. These inventions have also contributed to the growth of scientific knowledge. Will technological development continue to bring about major changes?

Turn to pages 213 and 214 of the textbook and read “Developing Future Technologies.”

teleportation: a hypothetical method of transportation in which matter is dematerialized, usually instantaneously, at one point and recreated at another

Going Further

You may have heard the popular line from *Star Trek*, “Beam me up, Scotty.” **Teleportation** is a futuristic technology to “beam” objects from one place to another. Interested in teleportation? Visit the following website to find out more:

http://travel.howstuffworks.com/teleportation1.htm

16. The scientific understanding of work and energy grew along with technological development. To illustrate the interconnectedness of science and technology, draw a timeline starting with the information in Figure B3.15 on pages 208 and 209 of the textbook.

    Now, review the terms of energy on pages 165 to 170 of the textbook. Then add the following scientific events to your timeline.

    - Bacquerel discovers radiant energy due to nuclear energy within atoms.
    - Black demonstrates that thermal energy flows naturally from a hot object to a cold object.
    - Carnot determines the maximum possible efficiency of a heat engine (in 1820).
    - Edison invents the light bulb, showing that electrical energy can be converted into light energy.
    - Faraday shows that a moving magnet could produce electricity in a nearby conductor.
    - Joule publishes the value for the amount of mechanical energy required to produce a unit of heat (in 1843).
    - Lavoisier discovers that chemical reactions produce thermal energy.
    - Oersted discovers that electric current has a magnetic effect.

- Seebeck builds a device proving that thermal energy can be converted into electrical energy.
- Thompson, after observing the boring of cannons, concludes that mechanical energy can be converted into thermal energy.
- Volta invents the first battery—the Volta pile—showing that chemical energy can be converted into electrical energy.
- Young concludes that mechanical energy is the sum of kinetic energy and potential energy.

Check Check your answer with the one on page 133.

Looking Back

You have now covered all the concepts for this lesson. You studied the development of engines and the nature of technological development.

17. Answer question 12 of "Check and Reflect" on page 214 of the textbook.

Check Check your answer with the one on page 133.

Go to ... Go to pages 3 and 4 of Assignment Booklet 2C and answer questions 8 and 9.

Glossary

internal combustion engine: a heat engine in which fuel is burned inside the engine itself (rather than in a separate furnace)

teleportation: a hypothetical method of transportation in which matter is dematerialized, usually instantaneously, at one point and recreated at another

Suggested Answers

1. The scarcity of trees led to the use of coal from mines as fuel. Water seeping into the mines had to be pumped out to prevent flooding. Powerful engines were needed to pump the water out of the deep mines.

2. a. The bottom valve opens during the half cycle when the piston moves to the left.

   b. The top valve is constructed so that it can move upwards when the water pressure below it is greater than the water pressure above it. With the bottom valve staying closed, as the piston moves inward (to the right), the water pressure increases to a magnitude greater than that above the top valve. This pressure imbalance forces the top valve open and keeps it open while the piston moves inward.

   As the piston moves outward (to the left), the water pressure decreases to a magnitude less than that above the top valve. The top valve is forced down (closed) by this pressure imbalance. With the top valve closed, water cannot flow down through the valve to equalize the water pressure. Therefore, the top valve remains closed while the piston moves outward.

3. Papin needed a large drum to build his steam-powered engine.

4. Atmospheric pressure forces water up the mineshaft pipe into the cylinder of the Savery pump.

5. a. iv b. iii c. iv

6. The Newcomen engine needed tremendous amounts of thermal energy to function because the cylinder had to be cooled after every heating. This led to a great loss of thermal energy.

7. The Watt engine was more efficient than the Newcomen engine because the cylinder was designed to remain hot rather than being cooled and heated over and over again.

8. The Watt engine needed a large, heavy boiler. In addition, the Watt engine was very inefficient at converting thermal energy into mechanical energy. These reasons made the Watt engine unsuitable for automobiles.

9. **Textbook questions 4, 5, 8, and 9 of "Check and Reflect," p. 214**

   4. The first attempt at developing an internal combustion engine involved gunpowder. Such engines were dangerous. The "external combustion" engine in the form of a steam engine was chosen as a safer alternative.

      Only when portable engines were needed for vehicles on roads were the large size and weight of steam engines an issue.

      The coal gas engine and the gasoline engine had to wait for the development of electrical circuits and dynamos to produce sparks. Also, the gasoline engine needed the support of refining technology for a supply of gasoline.

5. Watt considered the Newcomen steam engine highly inefficient because the same chamber was heated and cooled repeatedly to produce steam and then to condense the steam. Watt identified the constant reheating of the chamber as a waste of energy.

8. Daimler developed an internal combustion engine to run on gasoline rather than coal gas. This was an improvement because gasoline contains more energy than the same volume of coal gas.

9. The intake valve controls the inflow of the air-fuel mixture. The exhaust valve controls the outflow of the gaseous products of combustion.

10. Answers will vary. A sample answer is given.

Device	Type of motor or engine	Energy source	Importance to lifestyle
automobile	gasoline engine	gasoline	essential
blender	electric motor	electrical outlet	not essential
CD player	electric motor	electrical outlet	not essential
clothes dryer	electric motor	electrical outlet	essential
dishwasher	electric motor	electrical outlet	essential
refrigerator	electric motor	electrical outlet	essential
furnace	electric motor	electrical outlet	essential
hair dryer	electric motor	electrical outlet	not essential
lawn mower	gasoline engine	gasoline	essential
snowmobile	gasoline engine	gasoline	essential
string grass trimmer	gasoline engine	gasoline	not essential
vacuum cleaner	electric motor	electrical outlet	essential
washing machine	electric motor	electrical outlet	essential

11. **Textbook questions 1, 2, and 3 of "Minds On . . . Motors and Engines Today," p. 211**

    1. The most common type of engine or motor was the electric motor.

    2. The most common source of energy was electricity from a regular home outlet.

    3. Answers will vary. You may have been surprised at the number of devices you could do without or the number that you depend on for your lifestyle.

12. Answers will vary. Your paragraph should describe the importance of engines and motors to a modern industrialized society and include the following points:

  - Engines and motors reduce the amount of manual work needed on the job and at home. They make many labour-saving devices possible.
  - Engines and motors are essential in providing mechanical energy for large-scale manufacturing processes.
  - Engines and motors are essential to both public and personal modes of transportation.
  - Engines and motors are important in equipment used in research facilities.
  - Without engines and motors, modern industrialized society would not be possible. Lifestyles would be simple, like those of the time before the Industrial Revolution.

13. Results will vary. Sample data is given.

Modification Made to the Steamboat	Trial #	Time Taken for the Steamboat to Travel 15 cm (s)
original design	1	N/A moved in a small circle
	2	N/A moved in a small circle
moved medicine dropper a bit off centre through the back of the boat	1	27 s moved fairly straight
	2	24 s moved fairly straight
with medicine dropper still a bit off centre, added a third candle to heat the test tube	1	21 s
	2	25 s

14. **Textbook questions 1 and 3 of "Communicate," p. 213**

    Answers will vary depending on experimental results.

    1. The number of candles used to heat the water in the test tube affected the propulsion. With an extra candle, more thrust was produced and the boat travelled faster. The propulsion was also affected by the position of the test tube. If not positioned properly, the boat travelled in circles.

    3. The design was successful in producing enough energy to propel the steamboat. **Note:** You may not have been able to get the boat to move under its own steam.

15. Refer to the answer to question 14.

16.

1675

1680: C. Huygens experiments with a gunpowder engine.

1690: D. Papin designs the first heat engine.

1700

1698: T. Savery invents the first steam-powered pump.

1712: T. Newcomen patents a steam engine that uses a boiler to produce steam to move a piston in a separate pump.

1725

1750

1750: J. Black demonstrates that thermal energy flows naturally from a hot object to a cold object.

1763: J. Watt designs a new, more efficient steam engine.

1775

1794: R. Steele patents an engine fuelled by gas from tar and oil.

1800: B. Thompson (Count Rumford), after observing the boring of cannons, concludes that mechanical energy can be converted into thermal energy.

1800

1801: E. Lebon invents the first internal combustion engine.

1807: T. Young concludes that mechanical energy is the sum of kinetic energy and potential energy.

1820: H. Oersted discovers that electric current has a magnetic effect.
S. Carnot determines the maximum possible efficiency of a heat engine.

1825

1821: T. Seebeck builds a device proving that thermal energy can be converted into electrical energy.

1831: M. Faraday shows that a moving magnet could produce electricity in a nearby conductor.

1850

1843: J. Joule publishes the value for the amount of mechanical energy required to produce a unit of heat.

1867: N.A. Otto and E. Langen develop the four-stroke internal combustion engine.

1875

1883: G. Daimler designs an internal combustion engine that uses gasoline instead of coal gas.

1890: Mass production of automobiles with internal combustion engines begins in Germany.

1900

1896: H. Becquerel discovers radiant energy due to nuclear energy within atoms.

Early 1800s: A. Lavoisier discovers that chemical reactions produce thermal energy. A. Volta invents the first battery—the Volta pile—showing that chemical energy can be converted into electrical energy.

1801–1867: Various scientists, engineers, and inventors make improvements to Lebon's design.

Late 1800s: T. Edison invents the light bulb, showing that electrical energy can be converted into light energy.

17. **Textbook question 12 of "Check and Reflect," p. 214**

12. The internal combustion engine did not need a boiler. This allowed the internal combustion engine to be much more compact and lighter than the steam engine.

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Lesson 3

Useful Energy and Efficiency

The game of golf is fast becoming one of the more popular games to play in North America. Thanks to golfers like Tiger Woods, many people, especially youths, have taken up the game and have taken lessons.

One of the keys to golf is the ability to efficiently transfer as much of the energy in your swing as possible to the golf ball, making the ball fly further and straighter. Taking golf lessons from a carded professional teaches you how to achieve a controlled, efficient swing. It is a common sight to see golfers who swing "out of their shoes" be out driven by those who swing with control.

The concept of **efficiency** is applied to many other sports and systems around the world. In this lesson you will examine how efficiency is used to describe engines and other machines.

efficiency: a measure of how effectively a machine converts input energy into useful output energy

Turn to page 215 of the textbook and read the introductory paragraphs of "Useful Energy and Efficiency."

1. Refer to "*info*BIT" on page 215 of the textbook.

    a. What percent of the thermal energy released by the combustion of gasoline is used to keep an automobile moving forward?

    b. What percent is lost to internal friction?

2. Answer question 2 of "Check and Reflect" on page 220 of the textbook.

Check Check your answers with those on page 138.

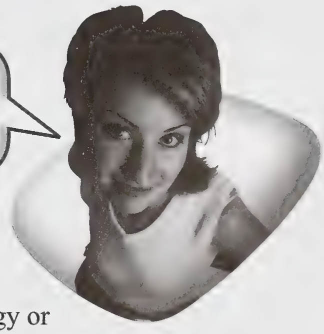
The conversion of thermal energy into mechanical energy always involves thermal energy loss. According to the second law of thermodynamics, this loss of thermal energy is unavoidable, even if losses due to friction could be avoided. Recall Figure B3.5 on page 203 of the textbook.

useful energy: energy needed to perform a task

All energy conversions involve some energy loss. Designing a device to operate efficiently can minimize such loss; and the device, then, provides an optimum amount of **useful energy**.

Turn to pages 215 and 216 of the textbook and read "Useful Energy" and the first part of "Efficiency."

Actually, the efficiency of a steam reciprocal engine is typically 25%–30%, not 50%–75% as indicated in Table B3.1.



3. According to the efficiencies of various technologies, which conversion is likely more efficient—electrical energy into mechanical energy or thermal energy into mechanical energy? Give a reason for your answer.

Check Check your answer with the one on page 138.

Seeing your exam or assignment score as a percentage rather than as a raw score helps you grasp the extent of your success. Similarly, percentages are used to express efficiencies in a meaningful way.

$$\text{percent efficiency} = \frac{\text{useful work output}}{\text{total work input}} \times 100\%$$

There are several specialized versions of this formula. The version you use depends on the type of energy conversion involved.

Turn to pages 216, 217, and 220 of the textbook and read three types of energy conversions/transfers given in "Efficiency." Work through the Example Problems B3.1, B3.2, and B3.3 carefully.

4. Answer questions 1, 2, and 3 of "Practice Problem" on pages 216 and 217 of the textbook.

Check Check your answers with those on pages 138 and 139.

In the next activity you will investigate the effects of dropping lead shot pellets. The pellets are not fragile, so they are not going to be broken, but they will be affected by an energy conversion that may surprise you.

Inquiry Lab

Efficiency of a Thermal Device (Teacher Demonstration)

Read the entire activity on pages 218 and 219 of the textbook.

5. Write a hypothesis for this activity.

Check Check your answer with the one on page 139.

Insert the Science 10 Multimedia CD into your computer. View the segment "Efficiency of a Thermal Device" to watch a demonstration of this activity.

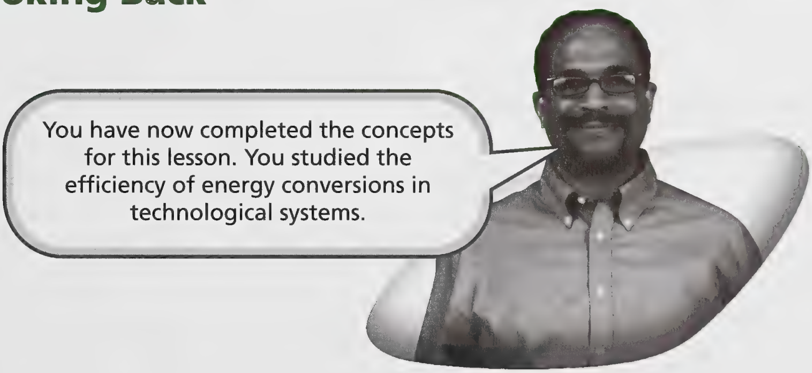
6. Copy the table given at the bottom of page 218 of the textbook, and record the results of the demonstration shown in the segment.

7. Answer the following on page 219 of the textbook.

   a. questions 1 to 5 of "Analyzing and Interpreting"
   b. question 6 of "Forming Conclusions"
   c. question 7 of "Applying and Connecting"

Check Check your answers with those on pages 139 to 142.

Looking Back



8. Answer questions 5, 8, 9, and 11 of "Check and Reflect" on pages 220 of the textbook.

9. Think about the process of hitting a golf ball (or baseball). What visual evidence suggests the transfer of energy to the ball is not 100% efficient?

Check Check your answers with those on pages 142 to 144.

Go to ... Go to pages 4 to 7 of Assignment Booklet 2C and answer questions 10 to 18.

Glossary

efficiency: a measure of how effectively a machine converts input energy into useful output energy

$$\text{efficiency} = \frac{\text{useful work output}}{\text{total work input}}$$

energy input: the initial energy source

percent efficiency: efficiency expressed as a percentage

$$\text{percent efficiency} = \frac{\text{useful work output}}{\text{total work input}} \times 100\%$$

useful energy: energy needed to perform a task

useful energy output: energy needed to do work

useful work output: work a machine is supposed to do

Suggested Answers

1. a. Only 14% of the thermal energy released by the combustion of gasoline is used to keep an automobile moving forward.

   b. Only 6% is lost to internal friction.

2. **Textbook question 2 of "Check and Reflect," p. 220**

   2. The exhaust system and cooling system each "waste" the same amount of energy. Each can be thought of as the component that consumes the most energy.

3. The conversion of electrical energy into mechanical energy is more efficient than the conversion of thermal energy into mechanical energy. The engines converting thermal energy into mechanical energy do not have efficiencies greater than 40%. According to Table B3.1, the efficiency of an electric motor (or engine) can be as high as 95%.

4. **Textbook questions 1, 2, and 3 of "Practice Problem," pp. 216 and 217**

   1. $$\begin{aligned}\text{percent efficiency} &= \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100\% \\ &= \frac{1.96 \times 10^4\ \text{J}}{5.61 \times 10^4\ \text{J}} \times 100\% \\ &= 34.9\% \leftarrow \text{3 significant digits}\end{aligned}$$

      The hoist is 34.9% efficient.

Note: When calculating efficiency, the units cancel. Efficiency, whether shown as a percent or not, has no units.

2. percent efficiency $= \dfrac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100\%$

$$E_{\text{m(useful output)}} = \frac{\text{percent efficiency} \times E_{\text{m(total input)}}}{100\%} \leftarrow \text{Re-order the formula to find the useful mechanical energy output.}$$

$$= \frac{(85\%)(15\text{ J})}{100\%}$$

$$= 13\text{ J} \leftarrow \text{2 significant digits}$$

The useful mechanical energy output of the motor is 13 J.

Note: You may remember seeing electrical energy expressed in kilowatt hours (kW•h). Expressing electrical energy in joules (J) can also be used.

3. The useful energy is the 125 J that go to heat the water (and beaker). The input energy is the 4.00×10^3 J of thermal energy released through combustion.

$$\text{percent efficiency} = \frac{\text{heat}_{\text{useful output}}}{\text{heat}_{\text{total input}}} \times 100\%$$

$$= \frac{125\text{ J}}{4.00 \times 10^3\text{ J}} \times 100\%$$

$$= 3.13\% \leftarrow \text{3 significant digits}$$

The Bunsen burner is 3.13% efficient.

5. Answers will vary. A sample hypothesis is given.

The greater the number of flips, the greater the thermal energy of the lead shot. This is because more mechanical energy is provided that will convert into thermal energy.

6.

Styrofoam Cup	Mass of Lead Shot m (g)	Initial Temperature t_{initial} (°C)	Final Temperature t_{final} (°C)	Average Height the Lead Shot Falls h (m)	Number of Times the Tube Was Flipped
1	305.29	23.9	24.0	0.585	8
2	303.21	23.9	24.1	0.590	16
3	301.71	23.9	24.2	0.590	24
4	302.23	23.9	24.4	0.590	32
5	300.63	23.9	24.5	0.590	40

7. a. **Textbook questions 1 to 5 of "Analyzing and Interpreting," p. 219**

1. Answers are based on the data indicated by the segment "Efficiency of a Thermal Device."

CHANGE IN GRAVITATIONAL POTENTIAL ENERGY OF LEAD SHOT

Styrofoam Cup	Mass of the Lead Shot m (g)	Acceleration Due to Gravity g (m/s^2)	Total Height the Lead Shot Falls h (m)	Change in Gravitational Potential Energy of the Lead Shot E_m (J)
1	305.29	9.81	4.680	14.02
2	303.21	9.81	9.440	28.08
3	301.71	9.81	14.160	41.91
4	302.23	9.81	18.880	55.98
5	300.63	9.81	23.600	69.50

the product of the values in columns 2, 3, and 4 in the same row divided by 1000

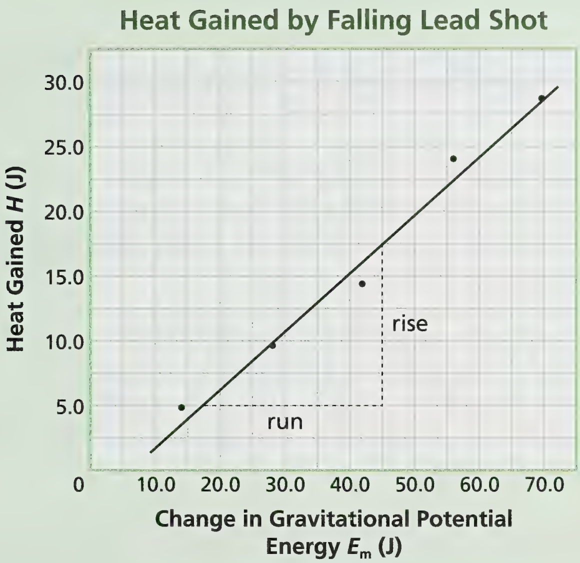
2. **HEAT GAINED BY LEAD SHOT**

Styrofoam Cup	Mass of the Lead Shot m (g)	Temperature Change Δt (°C)	Specific Heat Capacity of Lead c (J/g•°C)	Heat Gained by Lead Shot H (J)
1	305.29	0.1	0.159	4.854
2	303.21	0.2	0.159	9.642
3	301.71	0.3	0.159	14.392
4	302.23	0.5	0.159	24.027
5	300.63	0.6	0.159	28.680

the product of the values in columns 2, 3, and 4 in the same row

3. and 4.

Styrofoam Cup	Change in Gravitational Potential Energy of the Lead Shot E_m (J)	Heat Gained by Lead Shot H (J)
1	14.02	4.854
2	28.08	9.642
3	41.91	14.392
4	55.98	24.027
5	69.60	28.680



$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{17.5\text{ J} - 5.0\text{ J}}{45.0\text{ J} - 17.5\text{ J}} = 0.455$$

The slope of the line of best fit is 0.455 based on rise over run as indicated on the graph. This value represents an average of the efficiencies in the conversion of gravitational potential energy into thermal energy. The percent efficiency is 45.5% based on the slope.

5.

Styrofoam Cup	Change in Gravitational Potential Energy of the Lead Shot E_m (J)	Head Gained by the Lead Shot H (J)	Percent Efficiency of the Conversion Gravitational Potential Energy into Heat
1	14.02	4.854	34.63%
2	28.08	9.642	34.34%
3	41.91	14.392	34.34%
4	55.98	24.027	42.92%
5	69.60	28.680	41.21%
		Average	37.49%

Note: This average is based on the arithmetic mean of the efficiencies.

b. **Textbook question 6 of "Forming Conclusions," p. 219**

6. Answers will vary depending on the hypothesis you made. If your hypothesis stated that the thermal energy (heat) produced increases as the mechanical energy increases, then the data supports your hypothesis.

c. **Textbook question 7 of "Applying and Connecting," p. 219**

7. According to Table B3.1 on page 216 of the textbook, the automobile gasoline engine has an efficiency of up to 15%. Even compared to the car engine, the efficiency of the thermal device tested in this activity is low.

Note: Some sources of information rate the automobile engine efficiency as high as 30%.

8. **Textbook questions 5, 8, 9, and 11 of "Check and Reflect," p. 220**

5. a. The energy input is 1000 J.

   b. The energy output is 800 J.

   c. The energy output of 800 J is classified as useful work.

   d. The difference between the energy input and the energy output is classified as waste energy. In this case, it is 1000 J – 800 J = 200 J.

e. $$\text{percent efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100\%$$
$$= \frac{800\ \text{J}}{1000\ \text{J}} \times 100\%$$
$$= 80.0\%$$

The percent efficiency of the machine is 80.0%.

8. percent efficiency = 35.0%

$E_{\text{m(total input)}} = 1.20 \times 10^4$ J

$E_{\text{m(useful output)}} = ?$

$$\text{percent efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}} \times 100\%$$
$$E_{\text{m(useful output)}} = \frac{\text{percent efficiency} \times E_{\text{m(total input)}}}{100\%}$$
$$= \frac{(35.0\%)(1.20 \times 10^4\ \text{J})}{100\%}$$
$$= 4.20 \times 10^3\ \text{J}$$

The useful work done by the machine is 4.20×10^3 J.

9. The useful output energy is equal to the work that must be done to lift the object.

$$E_{\text{m(useful output)}} = W$$
$$= Fd$$

The force corresponds to weight of the object, and distance corresponds to the height to which the object is lifted.

$$\therefore E_{\text{m(useful output)}} = mgh$$

Rather than calculate the value of useful output energy separately, substitute the expression mgh for $E_{\text{m(useful output)}}$ in the formula for percent efficiency.

$$\text{percent efficiency} = \frac{E_{\text{m(useful output)}}}{E_{\text{m(total input)}}}$$
$$\text{percent efficiency} = \frac{mgh}{E_{\text{(total input)}}} \times 100\%$$
$$E_{\text{(total input)}} = \frac{mgh}{\text{percent efficiency}} \times 100\%$$
$$= \frac{mgh}{35.0\%} \times 100\%$$
$$= \frac{(2.00 \times 10^3\ \text{kg})(9.81\ \text{m/s}^2)(5.00\ \text{m})}{35.0\%} \times 100\%$$
$$= 2.80 \times 10^5\ \text{J}$$

The input energy required is 2.80×10^5 J.

11. Answers will vary. An internal combustion machine has an efficiency of less than 20%. A perpetual motion machine, theoretically, has an efficiency of 100%. The efficiency of an internal combustion engine is only about one-fifth that of the efficiency of a perpetual motion machine.

9. Answers will vary. The fact that the club is still moving after striking the ball indicates that not all the kinetic energy of the club was transferred to the ball. The swinging club after the ball has been hit is the visual evidence that the transfer of energy is not 100% efficient.

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Lesson 4

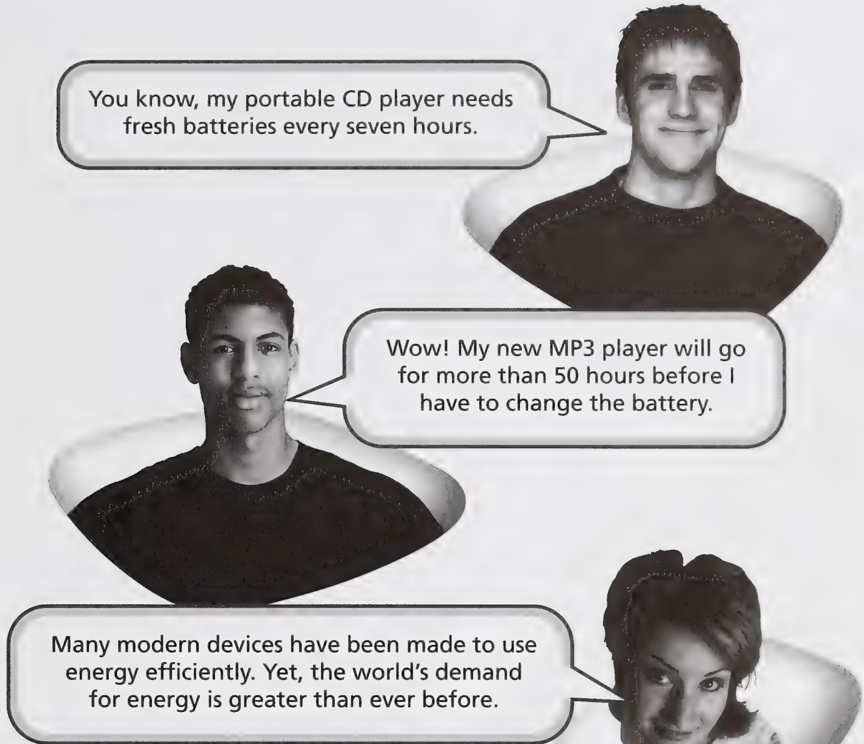
Energy Applications

According to many studies, breakfast is the most important meal of the day. Think of the word *breakfast*; it means "break the fast." It is the first food you consume after hours of fasting (time not eating while you sleep). Studies have shown that a good breakfast can improve your physical and mental performance. It is the energy supply from a well-balanced breakfast that is the key to an active, productive day.

Similarly, an energy supply is needed to keep technological systems operating. Turn to pages 221 and 222 of the textbook and read the introductory paragraph of "Energy Applications" and the information in "Energy Supply."

1. Answer questions 1, 2, 3, 6, and 7 of "Check and Reflect" on page 227 of the textbook.

Check Check your answers with those on page 150.



Turn to pages 223 and 224 of the textbook and read "Energy Demand" and "The Effects of Energy Use."

2. Refer to Table B3.2 on page 223 of the textbook. The global consumption of energy comes from various energy sources.

    a. Which source provides the most energy?
    b. Give an estimate of the total global yearly energy consumption in joules.
    c. Which of the energy sources is renewable?

3. Describe some negative, unintended consequences on the environment of energy use.

Check Check your answers with those on page 151.

You've read that the use of fossil fuels puts a strain on existing supplies and comes with unintended environmental consequences. Effective decision makers must consider both of these aspects when considering energy resources. In the next activity you will take on the role of a decision maker involved in the development of a power plant.

Decision-Making Investigation

Comparing the Energy Content of Fossil Fuels Used in Alberta

Read the entire activity on page 224 of the textbook.

If you are using the Internet to do your research, begin by visiting the following website:

http://scienceman.com/science10

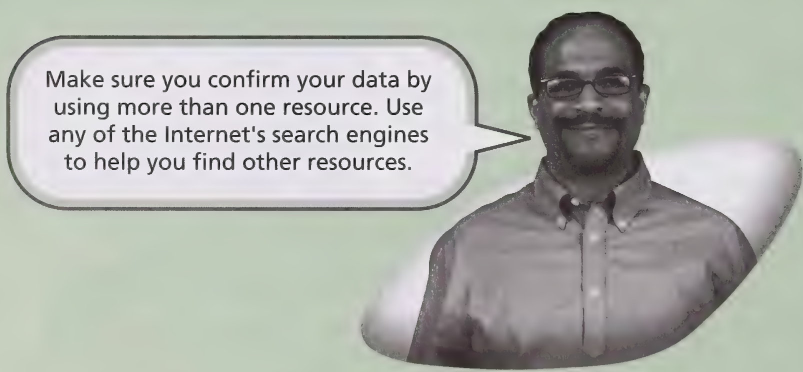
Once there, click on "Unit B: Hot Links." Then scroll down to Text Page 224 for a list of websites that will help you with your research.

Another website that may be helpful is

http://resources.yesican.yorku.ca/energy_flow/fuel2electric.html

4. Follow the instructions in question 1 of "Analyze and Evaluate." Use the following table to help you organize your information.

Source	Energy Content (J/kg)	Environment Effects	Projected Number of Years Left



5. Answer question 2 of "Analyze and Evaluate." Assume that the energy content of a fuel (in J/kg) has some relationship to the cost of transporting the fuel.

Check Check your answers with those on pages 151 and 152.

Going Further

To a group of people, present your decision as to which fossil fuel should be used in thermal energy plants in Alberta. Explain how you came to your decision; then answer any questions the group may have.

The energy content data shows the number of joules of thermal energy released by the combustion of 1 kg of the fuel. But when 1 kg of fuel is burned in an electrical power station, not much of the thermal energy is converted into electrical energy.

Turn to page 225 of the textbook and read "Minds On . . . Hydro Versus Coal-Burning Electricity Generation." It will shed some light on where energy losses are occurring.

6. Answer questions 1 to 4 of "Minds On . . . Hydro Versus Coal-Burning Electricity Generation" on page 225 of the textbook.

Check Check your answers with those on pages 152 and 153.

Going Further

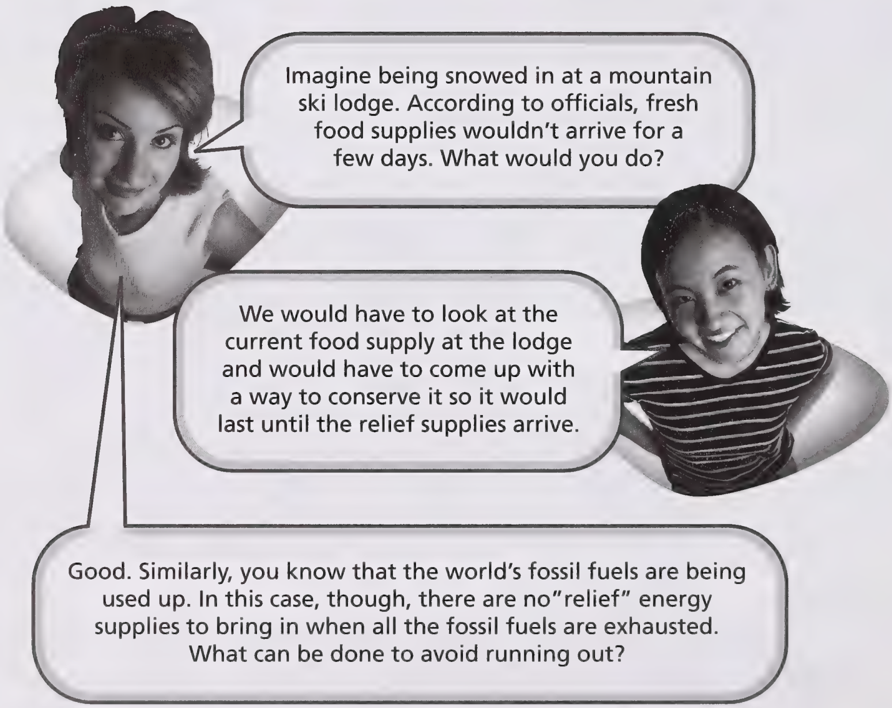
Have you noticed shopping malls near residential areas, dairy farms near cities, and schools within towns? There are good reasons for having such facilities where they are.

Find out why power stations are located where they are by completing "*re*SEARCH" on page 226 of the textbook.

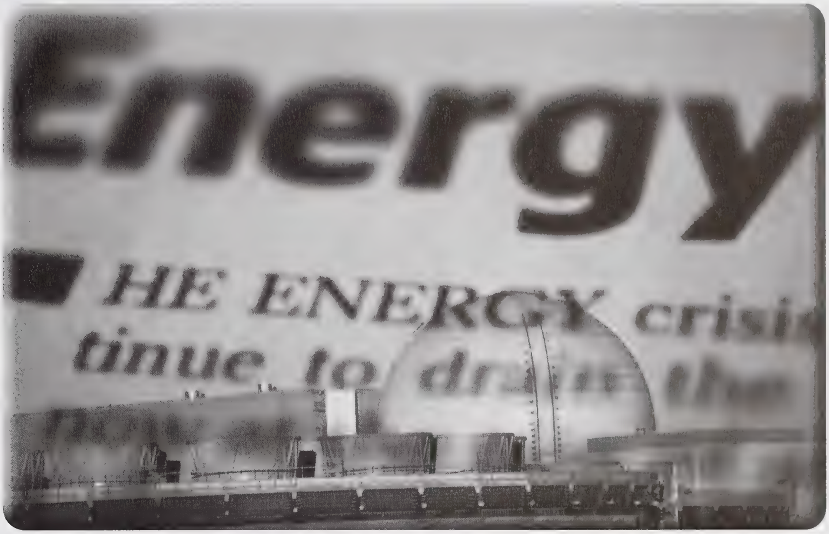
Begin your research at the following website:

http://www.scienceman.com/science10

Once there, click on "Unit B: Hot Links." Then scroll down to Text Page 226 for a list of useful websites.



Turn to pages 225 to 227 of the textbook and read "Energy Consumption and Conservation" and "Sustainable Development and Planning for the Future."



7. Answer questions 10, 11, and 12 of "Check and Reflect" on page 227 of the textbook.

Check Check your answers with those on page 154.

Looking Back

You have now covered all the concepts for this lesson. You investigated issues related to energy consumption and the use of natural resources.

8. Suppose you were helping to decide on a new kitchen stove and a second vehicle for your family. Based on the efficiency statistics at the bottom of page 226, what would your advice be?

Check Check your answer with the one on page 154.

Go to ... Go to pages 7 and 8 of Assignment Booklet 2C and answer questions 19 to 22.

Glossary

cogeneration: the use of waste energy from one process to power a second process

non-renewable energy source: an energy source that is limited and cannot be replaced

renewable energy source: an energy source that is continually and infinitely available

sustainable: of or relating to any process that will not compromise the survival of living things or future generations while still providing for current energy needs

sustainable development: the use of the world's resources in a way that keeps the resources for future generations

Suggested Answers

1. **Textbook questions 1, 2, 3, 6, and 7 of "Check and Reflect," p. 227**

    1. Answers will vary.

       Examples of solar energy sources include coal, natural gas, solar cell devices, wind energy, biomass, and biogas.

       Examples of non-solar energy sources include nuclear energy, tidal energy, and geothermal energy.

    2. The ultimate source of energy in the Sun comes from the hydrogen-hydrogen nuclear fusion reaction that occurs in the Sun's core.

    3. Biomass is any form of organic matter that has come from living things recently. Wood, seaweed, and animal wastes are examples of biomass.

    6. Fossil fuels were formed from the remains of plants and animals that lived eons ago. Plants store radiant energy from the Sun through photosynthesis.

    7. Photosynthesis is a direct use of solar energy from the Sun because the radiant energy from the Sun is used directly without first being converted into other forms of energy.

       The operation of a windmill is an indirect use of solar energy. The radiant energy from the Sun is not used directly by the windmill; it is first converted into wind energy (due to the uneven heating of Earth's surface by the Sun's radiant energy). Then the windmill uses this wind energy to produce useable energy.

2. a. Conventional oil provides the most energy globally.

   b. The sum of energy sources listed in Table B3.2 is 389×10^{18} J. This sum excludes energy from small sources, such as wind and geothermal sources. A reasonable estimate of the total global yearly energy consumption would be 400×10^{18} J (or 4.0×10^{20} J).

   c. Hydro is a renewable energy source.

3. Negative, unintended consequences on the environment of energy use include

   - drilling for oil in northern Alberta leaving scars on muskeg landscapes (in the Taiga biome)
   - leaking oil from wells, polluting surrounding areas
   - emitting oxides responsible for acid rain and greenhouse gases through the combustion of fossil fuel

4. **Textbook question 1 of "Analyze and Evaluate," p. 224**

   1. Answers will vary. The energy contents differ depending on the actual composition of the sources. For example, the energy content (J/kg) of coal depends on the type of coal. Sample data is given.

Source	Energy Content (J/kg)	Environmental Effects	Projected Number of Years Left
coal	4×10^7	• Strip mining destroys habitats. • Combustion of high-sulfur coal contributes to acid rain.	216
oil	4×10^7	• Oil spills release pollutants. • Drilling wells in muskeg leave scars on the landscape. • Exhaust gases have a fairly high impact on the environment.	40
natural gas	5×10^7	• Drilling wells leave damaged ecosystems. • Exhaust gases contribute to acid rain. • Some of the products of combustion release greenhouse gases and harm the ozone layer. • Incomplete combustion contributes to smog and releases particulates into the air.	62

5. **Textbook question 2 of "Analyze and Evaluate," p. 224**

   2. Answers will vary.

      For thermal energy plants, coal would be the best choice. The reserves of coal are far greater than the other fuels. It is a solid fuel, so its per-kilometre transportation cost would be higher than a fluid fuel, which can be moved economically via pipeline. However, the energy density (in terms of J/kg) is comparable to the other energy sources. So, not a great deal more mass of coal needs to be transported than the mass of another fuel. By keeping thermal energy plants near coal mines, transportation costs of the fuel as a deciding factor can be minimized.

      Natural gas is a clean source of energy, but its reserves are far less than coal. Oil reserves are even less. Oil is best kept for internal combustion engines, where it has a unique advantage as a fuel.

6. **Textbook questions 1 to 4 of "Minds On . . . Hydro Versus Coal-Burning Electricity Generation," p. 225**

   1. The number of conversions counted may vary depending how detailed they are split up.

Energy Conversions in a Hydro-Electric Power Station

gravitational potential energy (of water behind dam high above)

↓

kinetic energy (of flowing water in motion at level of turbine)

↓

kinetic energy (of rotating turbine)

↓

kinetic energy (of rotating coil in generator)

↓

electrical energy (in generator coil and out through transformer)

Energy Conversions in a Coal-Burning Power Station

chemical potential energy (stored in coal)

↓

thermal energy (of the combustion of coal)

↓

kinetic energy (of steam in motion)

↓

kinetic energy (of rotating turbines)

↓

kinetic energy (of rotating coil in generator)

↓

electrical energy (in generator coil and out through transformer)

2. In a coal-burning power station, thermal energy is lost due to the exhaust gases leaving the chimney, the spent steam that has passed the turbines, the friction of moving parts, and circuit electrical resistance.

   In a hydro-electric power station, thermal energy is lost wherever friction between moving parts is present and wherever there is electrical resistance in circuits.

3. It seems that hydro-electric power stations are more efficient because they have fewer energy conversions and fewer places where energy could be lost as heat. Of most significance, in coal-burning power stations, thermal energy must be converted into mechanical energy. This is an inefficient process.

4. Answers will vary. The following is based on the assumption that these plants are not running as efficiently as possible.

   Efficiency can be improved in both power stations by using better lubrication between moving parts to reduce friction and by using more efficient electric generators and transformers.

   Coal-burning power stations can be improved by insulating pipes carrying steam and any other parts kept hot. The combustion chamber can be designed for more complete combustion and better thermal-energy transfer to the circulating water.

   Note: Converting thermal energy into mechanical energy is inherently inefficient. Only part of the thermal energy can be transformed into mechanical energy according to the second law of thermodynamics. There will always be a significant amount of thermal energy that must be wasted.

7. **Textbook questions 10, 11, and 12 of "Check and Reflect," p. 227**

    10. An energy crisis is a crisis that occurs due to depleted energy sources or to the forecast of its depletion in the near future.

    11. Two short-term solutions to an energy crisis include the following:

        - Reduce the consumption of fossil fuel reserves through an energy conservation program.
        - Find new reserves of fossil fuels.

    12. The most practical solution to the energy crisis is to

        - reduce the consumption of fossil fuel reserves, which are non-renewable, by using more energy-efficient devices

        - develop new renewable sources of energy

8. Answers will vary but should show an awareness of the differences in energy consumption of various alternatives.

    For a new kitchen stove, get a gas stove. It uses half the energy an electric stove does. This comparison is based on the energy content of the natural gas used by the stove and the energy needed to generate the electricity used by the electric stove. (The electric stove itself is actually very efficient in converting electrical energy into thermal energy.)

    As for a second vehicle, consider a small, compact car. It will use half the energy of a large SUV. The second car will generally have only one occupant—the driver. So a small vehicle would likely do. If feasible, avoid purchasing a second vehicle. Take the bus, walk, or ride a bicycle.

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Conclusion

In this section you interpreted the first and second laws of thermodynamics. You used these laws to explain the operation of various devices and their theoretical limitations. You learned about the development of technologies during the Industrial Revolution that led to the scientific concept of energy. You then compared the efficiency of modern devices and considered the environmental impact of energy use.

Technologies that harness renewable energy sources help minimize the environmental impact of a modern lifestyle. One environmentally friendly technology is the wind turbine. Wind turbines produce electricity from an endless resource. They generate electricity without discharging pollutants into the environment.

Module Summary

In this module you examined energy flow in technological systems.

In Section 1 you discovered the relation between motion, work, and energy. You distinguished between uniform motion and accelerated motion, and you applied formulas and graphing techniques to gain insight into the way objects move. You then described speed as a scalar quantity and velocity as a vector quantity. You related the force on an object to a change in its motion and to the work done on the object. You used the scientific definition of work to develop the concept of energy.

In Section 2 you traced historical discoveries that clarified the concepts of energy and energy conversion. You surveyed a variety of forms of energy and used techniques to quantify various forms of energy. You applied the law of conservation of energy to explain how mechanical devices work and identified energy conversions that occur naturally and in technological devices.

In Section 3 you interpreted the first and second laws of thermodynamics. You used these laws to understand the operation of various devices and their limitations. You learned that the development of technologies during the Industrial Revolution was closely associated with the growth of the scientific concept of energy. You concluded the section with a comparison of the efficiency of modern devices and a reflection on the environmental impact of energy use.

Modern energy conversion devices have been designed to be effective and efficient. This came about through an understanding of thermodynamics. Rocket engines, automobile engines, steam turbines, refrigerators, and air conditioners are all based on thermodynamics.

One day, excursions into space may become common. The rocket engine that launches people into space will need to be effective and efficient in converting chemical potential energy into thermal energy and thermal energy into mechanical energy. The rocket engine design will be an application of thermodynamics.

Module Review

You have now covered all of the concepts for this module. To review what you covered, answer the following "Unit Review" questions on pages 232 to 235 of the textbook. If necessary, go back and read over parts of this module as you answer the questions.

1. Answer question 1 of "Vocabulary."
2. Answer questions 2, 5, 8, 13, 14, 19, and 26 of "Knowledge."
3. Answer questions 31, 32, 33, 39, 43, 53, and 57 of "Applications."

Check Check your answers with those on pages 158 to 161.

Suggested Answers

1. **Textbook question 1 of "Vocabulary," p. 232**

   1. *Acceleration* is the measure of the change in velocity in a unit of time.

      Cogeneration is using waste energy from one process to power a second process.

      Efficiency is a measure of how effectively a machine converts energy input into useful energy output.

      $$\text{Efficiency} = \frac{\text{useful work output}}{\text{total work input}}$$

      Energy is the ability to do work.

      The *first law of thermodynamics* states that the total energy, including heat, in a system and its surroundings remains constant.

      Force is a push or pull.

      Heat is the flow of thermal energy.

      Kinetic energy is energy due to the motion of an object.

      The *law of conservation of energy* states that energy cannot be created or destroyed.

      Potential energy is energy stored and held in readiness to do work.

      The *second law of thermodynamics* states that heat always flows naturally from a hot object to a cold object, never naturally from a cold object to a hot object.

      Sustainable refers to processes that will not compromise future generations.

      A *system* is a set of interconnected parts.

      Uniform motion is motion in a straight line at a constant speed.

      Velocity is the speed and direction of an object.

      Work is the transfer of energy from one object or system to another when a force is applied over a distance.

      $$\text{work} = \text{force} \times \text{distance}$$
      $$W = Fd$$

2. **Textbook questions 2, 5, 8, 13, 14, 19, and 26 of "Knowledge," pp. 232 and 233**

2. a. scalar
e.g., 5 km

b. vector
e.g., 5 km [N]

c. scalar
e.g., 100 km/h

d. vector
e.g., 100 km/h [W]

e. vector
e.g., 9.81 m/s^2 [down]

f. scalar
e.g., 50 J

g. scalar
e.g., 50 J

h. vector (also used as a scalar)
e.g., 98 N [down]

5. a. The object will speed up.
b. The object will slow down.

8. $$\begin{aligned} W &= Fd \\ &= (20.0\ \text{N})(1.30\ \text{m}) \\ &= 26.0\ \text{J} \end{aligned}$$

To lift the object, 26.0 J of work was done.

13. When the elastic is stretched an extra distance, it has more elastic potential energy. This will convert into more kinetic energy of the rock when the elastic is released. With more kinetic energy the rock has more speed.

14. The kinetic energy is greatest as the rock leaves the catapult. The gravitational potential energy of the rock is greatest at the highest point the rock reaches.

19. A heat engine uses heat to produce mechanical energy. Think of a jet engine, steam engine, or automobile engine. A heat pump uses mechanical energy to transfer thermal energy (heat). Think of a refrigerator or air conditioner.

26. Answers may vary. Two differences are given.

- The Watt engine burns its fuel outside the cylinder containing the movable piston. The internal combustion engine burns its fuel inside the cylinder.
- The Watt engine is powered by steam pressure acting on a movable piston. The internal combustion engine is powered by the pressure of hot gaseous products of combustion acting on the piston.

3. **Textbook questions 31, 32, 33, 39, 43, 53, and 57 of "Applications," pp. 233 to 235**

31. $$v = \frac{\Delta d}{\Delta t}$$

$$\begin{aligned}\Delta t &= \frac{\Delta d}{v} \\ &= \frac{180\ \text{km}}{90.0\ \text{km/h}} \\ &= 2.00\ \text{h}\end{aligned}$$

The journey will take 2.00 h.

32. a. $$\begin{aligned}\Delta d &= 10.0\ \text{m} + 10.0\ \text{m} \\ &= 20.0\ \text{m}\end{aligned}$$

This distance travelled is 20.0 m.

b. Let the direction up be positive and the direction down be negative.

$$\begin{aligned}\Delta \vec{d} &= (-10.0\ \text{m}) + (+10.0\ \text{m}) \\ &= 0.00\ \text{m}\end{aligned}$$

The displacement is 0.00 m.

c. $$\begin{aligned}v &= \frac{\Delta d}{\Delta t} \\ &= \frac{20.0\ \text{m}}{4.0\ \text{s}} \\ &= 5.0\ \text{m/s}\end{aligned}$$

The average speed is 5.0 m/s.

d. $$\begin{aligned}\vec{v} &= \frac{\Delta \vec{d}}{\Delta t} \\ &= \frac{0.00\ \text{m}}{4.0\ \text{s}} \\ &= 0.0\ \text{m/s}\end{aligned}$$

The average velocity is 0.0 m/s.

Note: No direction is needed when the magnitude is zero; it would be meaningless.

33. Let the direction north be positive.

$$\begin{aligned}\vec{a} &= \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t} \\ &= \frac{(+50.0\ \text{m/s}) - (0.00\ \text{m/s})}{(6.00\ \text{s})} \\ &= +8.33\ \text{m/s}^2\end{aligned}$$

The acceleration of the car is 8.33 m/s^2 [N].

39. $E_k = \frac{1}{2}mv^2$

$= \frac{1}{2}(2.30\times10^{-3}\ \text{kg})(2.50\ \text{m/s})^2$

$= 7.19\times10^{-3}\ \text{J}$

The kinetic energy of the bumblebee is 7.19×10^{-3} J.

43. $E_{k(\text{bottom})} = E_{p(\text{top})}$

$\frac{1}{2}mv^2 = mgh$

$v^2 = \frac{2\cancel{m}gh}{\cancel{m}}$

$v = \sqrt{2gh}$

$= \sqrt{2(9.81\ \text{m/s}^2)(15.0\ \text{m})}$

$= 17.2\ \text{m/s}$

The speed of the performer just as the cannon was fired was 17.2 m/s.

53. $\text{percent efficiency} = \frac{E_{\text{m(useful output)}}}{\text{heat}_{\text{(total input)}}}\times100\%$

$= \frac{350\ \text{J}}{1000\ \text{J}}\times100\%$

$= 35.0\%$

The efficiency of the steam engine is 35.0%.

57. a. The three major components of a coal-burning power station are the combustion chamber, turbine, and generator.

b. In the combustion chamber, thermal energy is produced from the chemical energy of the fuel. Some thermal energy is wasted through the exhaust gases.

In the turbine, mechanical energy through the torque of the rotating turbine is produced from the thermal energy of the steam. Some thermal energy is wasted on the steam that flows past the turbine. Some of the mechanical energy is lost as thermal energy due to friction.

In the generator, electrical energy is produced from the mechanical energy of the turbine, which is brought to the generator along a rotating shaft. Some energy is lost as thermal energy due to friction and to resistance of the electrical conductors.

SCIENCE 10

Energy and Matter in Chemical Change

Energy Flow in Technological Systems

Cycling Matter in Living Systems

Energy Flow in Global Systems